THE STORY OF IRON AND STEEL

THE SLAG PIT.
Loading slag into a freight car.

THE STORY OF IRON AND STEEL

BY

J. RUSSELL SMITH, Ph.D.

ASSISTANT PROFESSOR OF INDUSTRY, WHARTON SCHOOL OF FINANCE, UNIVERSITY OF PENNSYLVANIA

AUTHOR OF "THE ORGANIZATION OF OCEAN COMMERCE"

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PREFACE

This little volume, the outgrowth of courses in American industry, is an attempt to present the main facts of iron and steel making so that any intelligent person can grasp the essence of the complex technical phenomena of iron and steel making without even having to meet technical terms. The constant object has been to make every paragraph intelligible to the lay reader, and, in addition to presenting an understanding of the main technical facts, the major object has been to point out the economic significance of it all, for iron and steel are absolute fundamentals of the present industrial state.

I wish to express my indebtedness to the following authors and works upon whom I have freely drawn: J. Lowthrian Bell, F.R.S., " Manufacture of Iron and Steel "; Campbell,

"The Manufacture and Properties of Iron and Steel"; Swank, "Iron in all Ages"; F. Poplewell, "The Iron and Steel Production in America"; E. S. Meade, "Trust Finance."

I am personally indebted to my colleague, Prof. E. S. Meade, for valuable suggestions, and to a number of iron manufacturers (who do not wish their names mentioned) for much useful information.

J. Russell Smith.

Wharton School,
University of Pennsylvania,
Philadelphia, January, 1908.

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CHAPTER I

IRON ORES AND THEIR FORMATION

THE crust of the earth contains the seventy elements recognized by chemists as constituting all known matter. Among the seventy are half a dozen or so which we know as the useful metals, and of these iron is by far the greatest in quantity, the cheapest, and, most fortunately for mankind, the most useful.

Iron is everywhere, but not in its pure state. It is one of the peculiarities of nature's way of disposing of the elemental materials that almost none is to be found in its pure state, and when so found, it is a rare exception. Iron is one of the most elusive of the metals in the respect of its rare occurrence in the pure state. Indeed, it is very difficult to obtain pure iron in the laboratory, and the iron of commerce is never pure.

Like other metals, it is distributed widely

throughout the surface of the earth, and apparently it is rarest in that part of the earth's crust to which man has access. Astronomers, as they weigh the spheres in the invisible balances of their mathematical minds, report that the average weight of the earth is much greater than the weight of the surface which we can see. This inequality is caused by the occurrence near the center of the earth of vast masses of metals, iron included. If some Jules Verne could delve a few thousand leagues beneath the surface of the earth he would doubtless come to such mountains of iron as man has never dreamed of. Some estimators think that as much as a fifth of the whole content of this globe is iron. Man's opportunity for getting at these riches, however, is limited thus far to the surface of the earth and to about five thousand feet beneath it—merely the planet's skin. In this small fraction of the earth's mass are all the available supplies of the good metals. Only by the uncommon occurrences of nature have these been collected in masses which are sufficiently rich for our use. Only here and there has there been such a combination of circumstances as to make any of the metals available for immediate use; but fortunately the conditions for the collection of available iron have been brought into

combination more frequently than for any of the other metals.

Iron in its wide distribution often occurs in unsuspected forms. Whenever, as we go up and down, we see a red-colored surface, or a reddish tint upon the solid substances of the earth, we see iron—the bank of red clay, the red brick, the red paint upon the house wall, the complexion of rosy youth, or my lady's ribbon. Even the rosy apple derives its tint from iron which it contains; and the orchardist who selects his apple land sees to it that it contains iron to color the fruit which he hopes to sell. Further than this, the iron which is so common upon the earth's surface occasionally falls from heaven in the form of meteors; indeed, meteoric iron is about the purest which is found in all nature, and strange to say, the meteoric iron has a surprising degree of uniformity and always contains with it a small amount of nickel. However, this choice quality of iron does not come to us in quantities sufficient to serve a use more important than that of specimens for museums.

The chief condition which contributes to make available this widespread but unusable stock of iron is the fact that it is soluble in water; that is the real reason why the surface

of the earth possesses so much less iron than does its interior. For unknown millions of years the rain has been falling upon the hillsides, taking a minute quantity of iron into solution and carrying it away to the sea, and burying most of it beyond the reach of man. In all ages conditions arise here and there which cause the water to drop its iron. We then have the conditions for the formation of the ore iron upon which the iron industry rests. Certain lakes throughout many parts of the world possess minute organisms having the power to cause the iron in the water to be deposited on the bottom of the bog or lake in the form of a fine powder. This is called bog ore; and in some parts of the world it has been at times of importance in the manufacture of iron; for example, certain bog deposits in eastern Massachusetts furnished that commonwealth with iron for more than a century in the colonial period. The conditions which make for the deposit of bog ore are still in existence. The flowing waters continue to dissolve iron from the hillsides and the organisms in the ponds continue to precipitate it to the bottom. In parts of Sweden there are some of these lakes where the resulting iron-ore crops have long been harvested from time to time, the deposit in a few years or decades again becoming of suffi-

cient thickness to make profitable its collection for smelting.

This bog ore has doubtless been formed in past times in the same manner; and we have here a probable explanation of the peculiar fact that in some parts of the world, particularly in England, this ore is mixed largely with coal, the coal and iron having been deposited in the swamp simultaneously. The fact that coal is always, and iron is usually a swamp product, is a partial explanation of the fact that in many parts of the world we find the two closely associated —a fact of very great industrial importance, because the coal is now necessary for the smelting of the ore. This particular coal-ore compound, as found at Cleveland, England, actually contains about enough coal to provide for the satisfactory smelting of the ore. This, however, is quite unusual.

Limestone is the most common agent for the bringing about the deposit of the iron from the water in which it is dissolved. It is a peculiar fact that water containing iron, coming in contact with a stream containing lime, is compelled to drop the iron. The consequence is that wherever there are limestones we have the possibility of iron ore being deposited through the simple flowing of spring water over limestone. This

process often takes the form of the water-dissolving pockets in the limestone, and afterwards depositing iron in the place from which the limestone has been dissolved. Such was the formation of the famous Cornwall iron deposit in Pennsylvania, and of many similar deposits in this and other countries. We quite commonly find iron-ore deposits along the edges of limestone deposits; and geologists tell us there are long strings of iron ore reaching in an almost continuous line from New York, through Pennsylvania, Virginia, and on to Alabama. Furthermore, these deposits are not in a single string, but in a number of strings, the explanation being that they lie along the edges of the limestone outcrops which run through this region. The famed fertility of the Shenandoah and Cumberland valleys, sometimes known together as the great Appalachian valley, is due to the same limestone that produced the numerous ore deposits that made their early iron industry. The same alternation of limestone with other formations occurs in the other parts of the Appalachians, and has given us ores in the western hills and in the upper Ohio Valley, and especially western Pennsylvania.

There seems to be a slightly different explanation of the widely known and justly famed

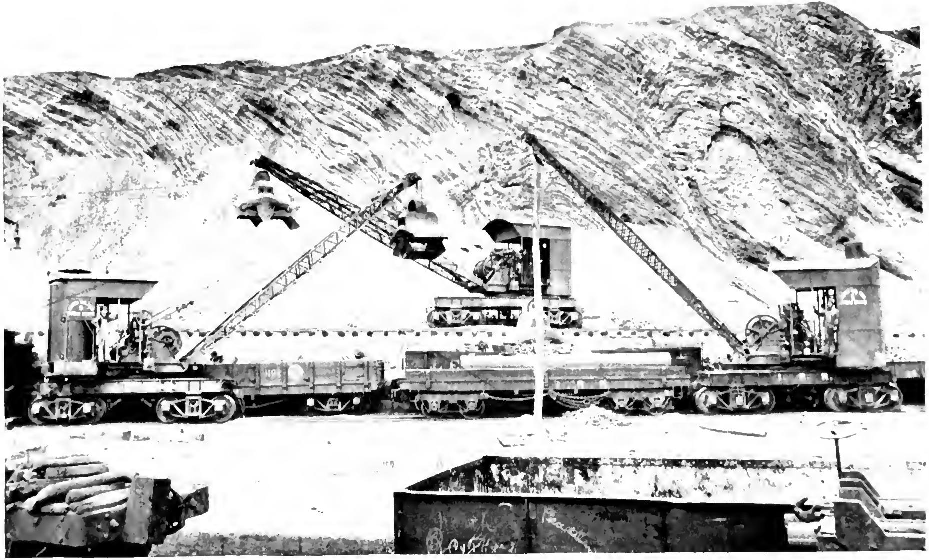
ore deposits around Lake Superior. Here are found iron ores in greater masses and greater richness than in any other part of the world. The rocks in which they are found are very ancient, and the geologists were at a loss to explain the almost fabulous ore deposits there existing, and particularly the very irregular shape and large masses in which they were found. Of late the commonly accepted explanation of this most fortunate occurrence is as follows: For vast periods of time water containing small quantities of iron appears to have trickled deep beneath the earth's surface through rocks which slowly decomposed, and as the rock dissolved, particle by particle, iron was deposited in its place, until it replaced the original rock. Thus was formed the petrified wood of the West, and the present great iron-ore masses which the prospectors in the Lake Superior woods are constantly exposing.

This combination of circumstances—first, the commonness of iron throughout the whole of the surface of the earth; second, its solution in water; and, lastly, its deposit wherever this water comes in contact with certain organisms or limestone—has given to man a world-wide distribution of iron; and, furthermore, it is in

forms more available and more abundant than those of any other of the great metals. It is only exceeded by aluminum, which we have thus far not learned to win for common uses.

These iron deposits which have been so praised are masses of ore which, as might be expected from the proclivities of iron and from the nature of ore deposits, are rarely pure ore; even the ores are mixed with foreign matter. The foreign substances are chemically separate from the ore with which they are mixed, and the ores themselves are of many varieties.

Ores may be classed in three great groups: First, oxides, or combinations of iron and oxygen; second, the carbonates, or combinations of carbon; and, third, the combinations with sulphur. In the order of their richness the ores are as follows: First, magnetite, an iron oxide (Fe_3O_4), which, when absolutely pure, may have as much as 72.40 per cent of iron. Second, hematite, a so-called sesquioxide (Fe_2O_3), which is almost as rich as magnetite, having a possible 70 per cent of iron. This ore occurs in different colors and in a number of forms. Third group, limonite, or watery oxides ($2Fe_2O_33H_2O$). This group contains the bog ore above described and some other less important ores. It is quite natural, considering their method of formation, that they



LAKE SUPERIOR OPEN-CUT ORE MINE.

should contain water so intimately mixed with the ore that it can be got rid of only in a furnace; consequently these ores can only reach a possible height of 59.89 per cent of iron. Fourth, siderite. This is a carbonate ($FeCO_3$). It is sometimes called spathic ore, and sometimes clay ironstone, when there is much clay in it. It is also the same ore that occurs in mixture with coal; and when this is the case it is called black band. It is of very little importance in America, but of considerable importance in Great Britain. The last member in the ore group is the sulphide, pyrites (FeS_2).

Owing to the fact that the ores are always mixed with foreign matter—clay or ordinary earth—or with a great variety of compounds, the ores rarely reach their full possible content by at least ten per cent. This impurity, which make ore leaner, must be extracted by some cheap means, and if possible before it goes to the furnace. This end is attained by a variety of devices, the simplest being sorting and sizing. The workmen pick out the stones and foreign matter by hand, leaving the good ore. The mass is sometimes washed when the foreign matter, like clay, is soft and can be removed by the action of the running water. A third method is the piling of the masses of ore, dirt, shale,

and other foreign stones, so that the action of the frost and the rain will break them apart, and the undesired can then be easily taken out by hand. The fourth method of ore purification is the roasting of ores. This is commonly applied to the sulphides, as by no other means can the sulphur be driven off. The heat of the furnace causes this troublesome substance to rise in sulphurous fumes, leaving the ores to be treated later, as are other ores. A fifth method of ore purification, by the use of magnets, is only applicable to magnetite. Strange to state, this valued ore is unlike all other ores in that it, like finished iron, will be attracted by the electric magnet, and by that means bits of ore can be picked out of the masses of foreign stone. If all other ores were capable of this treatment the world would be tenfold richer in iron; because by that means ores of very low iron content could be mechanically picked over; whereas at the present there has been devised no satisfactory means of separating the small amount of good iron from the large amount of clay, dirt, or stone which so much resembles it in all physical characteristics.

These impurities above mentioned, such as water, carbon dioxide, dirt, and stone, simply serve to make the ore poor, by diluting it, and are in

that respect directly unlike the three impurities of sulphur, phosphorus, and titanium; these substances, usually occurring in what might appear insignificant quantities, have the unfortunate effect of rendering the iron practically useless, because of the great brittleness which they add to it. For example, an ore containing one pound of phosphorus to a thousand pounds of iron is practically useless unless some means can be devised to get rid of the phosphorus. This was for a long time impossible, and consequently mountains of phosphatic ore were worth no more to mankind than mountains of vulgar stone, and upon the conquest of this scrimption of phosphorus hinged one of the greatest revolutions in the history of iron making.

CHAPTER II

THE EARLY HISTORY OF IRON

STATED briefly, iron is made by putting the ore into a fire that is hot enough to melt out the iron, which then trickles to the bottom of the mass. The metal which is thus won has, as everyone knows, the characteristic of promptly getting rusty. Iron rust, or iron oxide, as it is technically called, is formed by the union of the iron and the oxygen of the air; the process is called oxidization. It is nothing less than a return to the ore. In a few short years this process causes the farmer's wire fence to drop to pieces, eats the nails out of the buildings, puts holes in the roof, and in a generation or two rusts large pieces of iron into a powdery, brown heap. Because of this prompt destruction of iron, it is prone to disappear with the bones of the men who make it. The consequent rarity of its occurrence in prehistoric remains, influenced scholars for a long time to harbor the incorrect inference that the ancients knew nothing of iron. This inference, however, is entirely erroneous.

The manufacture of iron, even among many of the semisavage tribes, has been for ages widely distributed. There has been no civilization of which we have record that has not made use of iron. When, where, or how the first iron was made history will never tell, for iron is older than history. Its discovery may have been by accident. The great silver mines of Potosi in South America, so runs the story, were discovered through the melting of the silver by a camp fire. Another camp fire, in another part of the world, may have discovered to man the first lump of iron; a lightning bolt from heaven may have been the agent; or a forest fire, sweeping over great tracts of wilderness, may have resulted in its discovery. There is a record that in the fifteenth century before Christ the natives of Crete first learned from a forest fire that the ores of their island would make iron.

According to the classifications of some historians, iron was not the first metallurgical work performed by primitive man. History prior to definite dates is sometimes divided into the following epochs: The rough stone age, the smooth stone age, the bronze age, and the iron age. There is, however, no certainty that bronze preceded iron, although its priority is suggested by ancient remains, and by the fact that it is made

of copper and tin, two metals which occur occasionally in their pure state, and whose extraction is, therefore, a matter of great simplicity.

In 1837 explorations beneath the great pyramid of Gizeh revealed a small piece of iron, used in the structure of that great monument, and therefore probably dating back to four thousand years before Christ. This exceptionally long life for a bit of iron is only explained by the fact that in the exceedingly dry climate of Egypt the process of rusting goes on very slowly. Iron was not cheap in the Egyptian lands, else it would not have been the spoil of the conquering monarchs, but its use is widely indicated by the pictures remaining upon the walls of existing ruins. Ruins of large iron works have been discovered on the Peninsula of Sinai, and there is much evidence that iron was well known to the Assyrians, Chaldeans, and Babylonians, who occupied the plains of Mesopotamia for several millenniums before the time of Christ.

The Hebrews were well acquainted with iron. So early as in the fourth chapter of Genesis, Tubal Cain, born in the seventh generation from Adam, is introduced to us as "an instructor of every artificer in brass and iron." When the Israelites went into Canaan, the natives of that land fought them from iron chariots; the terri-

ble Og, King of Bashan, had an iron bed, and the spearhead of Goliath weighed six hundred shekels of iron. Job mentions both iron and steel when he says, "He shall flee from the iron weapon, and the bow of steel shall strike him through." Numerous other Scripture references show the familiarity of these people with iron.

The Greeks also were conversant with the metal, although in the Homeric poems its mention evidently indicates that it was rare and precious. Some centuries later, in Alexander's day, four kinds of steel were described, with their fitness for different uses, and Alexander took plunder of iron from the conquered princes of India. In the third century B.C., the Roman carpenter, mason, and shipwright used iron tools, and Pliny tells us that "iron ores are to be found almost everywhere." But the Romans had been preceded in the knowledge of iron by the people of Spain, who even before the Roman times were famous makers of iron. This the Romans learned to their sorrow when the Spanish swords in the hands of Hannibal's men mercilessly cut down the more poorly equipped Romans at Cannæ, 216 B.C.

Cæsar found the Britons in possession of iron which they had made; the Scandinavians were

also masters of both iron and bronze in Roman times, as evidenced by the remains of Viking boats. This iron, though its use was widespread, was everywhere dear, and may almost be ranked as a precious metal. Nor did a thousand years of Christendom do aught to cheapen it. As late as the fourteenth century it was too costly to replace brass in the kitchenware of the ordinary dweller of England, who used steel only where its great strength and cutting ability were required, as in hoes, scythes, forks, and, above all else, in swords. The victory of William the Conqueror, at Hastings, in 1066, was attributed by him largely to the superior weapons of his men, and he exalted the smith, who was also a sword maker, to a rank equal to the highest official, a position which the British blacksmith held through several centuries, while the might of armies rested upon the excellence of the sword.

From the beginning of iron making, before the dawn of history, down almost to the time when Columbus set sail to discover America, there was surprisingly little progress in the process of the manufacture of iron, and, indeed, there was some loss of knowledge of the art. Most of the early methods of making iron, which have in modern times been replaced by astonishing improvements, are still to be found in oper-

ation in remote corners of the world. Less than half a century ago explorers in central Africa described the modern method of iron making in that country. Two men squat over a charcoal fire, which is between them. Both urge it on with hand bellows, and charge it alternately with lumps of charcoal and lumps of iron ore. The result of the day's labor of these two men is a dozen pounds of iron. Even in Roman times in Britain and in Belgium iron was made in a conical hole in the ground. This hole was dug in some hilltop with free access to the prevailing wind which rushed through a converging tunnel into the bottom of the fire hole. This primitive forced draught could only be used on days when the prevailing wind blew. At other times the furnace had to be idle. This exceedingly primitive method is not, however, typically descriptive of even very ancient iron making, for history knows not when the bellows was invented. There were other very early methods of making the forced draught necessary for the slowest iron making. In the monsoon countries of southeastern Asia, where the bamboo grows, as in India, Burmah, Borneo, and even Madagascar, the natives early discovered that by working loose pistons through a hollow bamboo, practically as we work a pump, they could force

air through their fire, and by this means they made iron before the Christian era. This bamboo device is a near ancestor to the modern air pump. Possibly a more ingenious device is the goatskin bellows, widely used throughout the world, and pictured thirty-five centuries ago upon Egyptian walls. The operator has two goatskins, one under each foot, both connecting with the same pipe, for carrying the air to the fire. When the bellows is full of air, the weight of the operator forces it into the fire. At the same time he pulls a string, which inflates the other goatskin through a hole in the upper part. Over this hole, when the skin is full of air, the operator deftly places his bare heel, and his weight starts a current of air from the second goatskin. In the meantime the first is being filled in a similar manner, and thus a constant blast is maintained.

The primitive methods of the ancient world finally focused themselves, so far as the Mediterranean basin and European countries were concerned, upon the so-called Catalan forge, which was first devised and used in Catalonia, Spain. This differs but little from the ordinary blacksmith forge, which has the air blast furnished by a bellows, or if possible by a waterfall through the device known as the trompe.

This consists in letting the water fall through a pipe and carrying with it bubbles of air, which escape at the bottom of the pipe into

Catalan Furnace

an airtight receptacle. There the accumulated air has a pressure derived in being carried downward in the falling water. The primitive iron

maker, however, who used the Catalan forge had the option of making his iron where a waterfall would give him the desired air blast, or if it involved less labor, he could use his muscle, and make a bellows blast near where there was an abundant supply of ore, rather than carry the ore to the waterfall. Both methods were used; and clinkers are found high up on the Pyrenees, far removed from water.

The Roman iron industry in Britain was prosecuted with considerable vigor, as shown by the large clinker deposits which they have left. At a later time these tailings left by the Romans served for several centuries as a profitable basis for iron smelting, so rich were they in good iron, which the Romans themselves could not extract. Some careful experiments recently made with the old Roman method of making iron have led to the conclusion that it could not now be so made for less than $1,000 a ton. This may well explain why the Roman Coliseum, in which each stone was held to its neighbor by iron clasps, has for centuries shown only gaping holes, where some enterprising vandals have cut the rock to get the small piece of iron.

The Catalan forge (devised no one knows when) was the staple and standard method of iron making through the Middle Ages. After-

wards, the Germans by a series of slow improvements evolved the first form of blast furnace. Before this time iron had not been melted. The primitive forges merely produced a lump of crude iron at the bottom, which was hammered, to make it ready for the various uses to which it was put. It should not, however, be inferred that because the iron was costly and the methods primitive the quality was inferior. If we may believe half the stories which we read about the excellence of the swords of Toledo, Bilboa, and the Damascus blade, the world has lost something of the art of tempering steel. It is plain that Asia knew less in 1800 about the making of iron than she knew twenty-five hundred years before. There is in India a column sixteen inches in diameter, weighing seventeen tons, the whole of malleable iron, and dating back at least twenty-five hundred years, during most of which period the Asiatics have had at their control no method of duplicating this splendid piece of metal. Asia made as much iron, and as good iron, and probably applied as good methods in the time of Nebuchadnezzar as in the time of Queen Victoria. A French Royal Commission in 1880 found in Cambodia a locally famous iron district which was exporting iron over a wide area at a cost of about three hundred

dollars a ton. It was made by one of the above-mentioned primitive devices. The quantities used were small, but served to supply the simple needs of the primitive Indo-Chinese.

While for five centuries the blast furnace has been important, the Catalan forge or its equals is not limited to such remote regions as Cambodia or the head waters of the Nile. Twenty years ago it was used for making iron in its original home, the Pyrenees, in France, in the Appalachian regions of the United States, where in secluded valleys, remote from the railway, far beyond any good road, the American mountaineer still worked the little forge to make his iron, while his wife worked the spinning wheel to make his clothes. But these are economic bayous which stagnantly branch off from the main stream of iron making, which has in the past centuries flowed with an ever-increasing tumult of improvement.

CHAPTER III

THE BEGINNING OF MODERN IRON MAKING AND ITS INTRODUCTION INTO AMERICA

MODERN iron making may properly be said to have begun with the achievement of the blast furnace and the resulting making of cast iron. The forges which had been used from time immemorial and finally resulted in the Catalan forge did not succeed in melting the iron so that it could be poured. It merely made a lump of metal of fine quality, which could be heated red-hot and refined and hammered into iron and steel. As stated in the last chapter, the excellent quality of this forge iron is witnessed in the achievement of the Saracen sword makers, whose Toledo and Damascus blades have never been excelled. But at best it was a costly and slow method, comparable to the work of the silversmith, and as little suited to meet the needs of a modern machine civilization as is a canoe for attending to our ocean traffic. The lump of forge iron, or, as it is sometimes called, the bloom, from the bloomary, was comparatively

small, rarely being above one or two hundred weight in size.

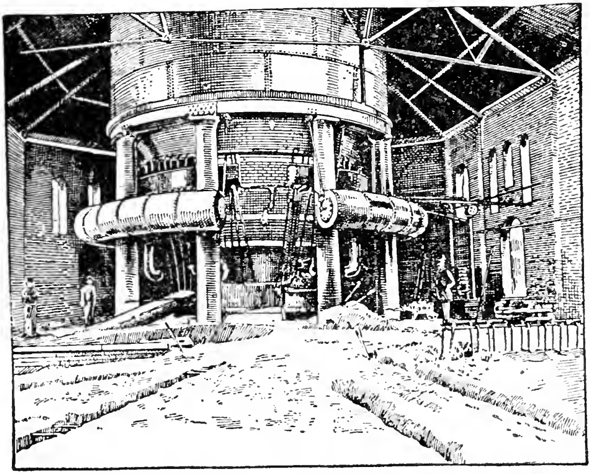
After the decline in the iron maker's art, which accompanied the general lapse of knowledge during the mediæval period, the iron industry first revived in the lower Rhine Valley, where, in the latter part of the mediæval period, the Germans had an improved form of the Catalan furnace, which they had built to a height of ten to sixteen feet, and called the *stückofen.* It was sometimes called the wolf oven, so named because the metal resulting from its operation was called a wolf. This furnace had an output in its best form of 100 or 150 tons in the year, and represents the final form of the Catalan forge in Europe.

The next stage was merely the enlargement of this German *stückofen* to a greater height. It was rechristened the blow oven, and the greater heat of its flame succeeded in melting the iron and making it flow so that it could be cast. This improvement may properly be said to have resulted in the blast furnace, first used in Belgium, about 1340. It should be noted that there is a great resemblance in the names "blow oven" of the German and "blast furnace" of the English. This device was improved and perfected during the fifteenth and sixteenth cen-

turies by the Germans, Belgians, and the French. Strange to say, it was nearly two centuries before it was widely introduced into Europe, not being known in Saxony until 1550, although it was used in England a century earlier. By 1550 in central Germany its bellows were worked by cams upon the axles of water wheels, which also operated heavy hammers for the purification of the metal.

By 1680 a blast furnace in the Forest of Dean, England, was described as being thirty feet in height, operating continuously for months, and making cast iron, which was described under the names of sows and pigs. Pig iron is the crude product of the blast furnace, and bears its bucolic name because the molten iron is allowed to run from the furnace, over a floor of sand, in which are impressions into which the iron is permitted to run and cool in any shape desired. The most convenient shape is the one by which little side depressions lead off from a main trench in the same way that cross streets leave a main avenue. These depressions on the casting floor are separated by very narrow sand banks, causing the main channel and the side channel when cast into iron to considerably resemble a family of infant swine feeding; hence the name pig iron.

Charcoal has been the universal fuel for the smelting of iron among savages and among all civilizations from the earliest date down to the successful introduction of coke about the middle of the eighteenth century. Therefore, for-



Pig Iron Casting Floor by a Modern Blast Furnace

ests to supply wood to be burned into charcoal were a very important part of the natural equipment for the making of iron. In a small country like England this pressure was soon felt, and as early as the reign of Elizabeth the devastation of the forests caused Parliamentary action

prohibiting the establishment of more furnaces in certain counties. The British iron industry, thus restricted by law and by the open fields that it produced, followed the vanishing forests from one county to another. In 1719 the resulting devastation was again violently assailed in Parliament; but the scarcity of charcoal in Great Britain had already resulted in the relative decline of the industry in that country in comparison to Germany, with its better forest resources. In 1749 England was making 18,000 tons of iron per year and importing 20,000 tons from Germany.

As early as 1619 a man by the name of Dud Dudley had succeeded in making charred, or partly burned, coal serve the purpose in his blast furnace, but this was not very profitable, and his equipment was broken up by the outraged charcoal burners, who saw in his improvement the threatened ruin of their business. It was not until more than a century later, through the activity of one Abram Darby, of Coalbrookdale, that the successful introduction of charred coal or coke as an iron-making fuel came about. This discovery, like that of the blast furnace itself, did not revolutionize the iron industry of the whole world. In America, for example, its introduction did not come until late in the nine-

teenth century, because of the lack of development of coke-making coals and the abundant supply of other fuels. Coke-made iron, like the blast furnace, was limited to certain favored districts. It had its quickest development in England, where its discovery came in the nick of time to save the declining iron industry from extinction.

The early making of iron in America and its continuance until far past the Revolutionary period was entirely supported by charcoal, of which the country had an abundant supply.

As early as 1585 Sir Walter Raleigh's unsuccessful expedition brought back from North Carolina glowing accounts of iron ore. The early Virginia colonists were confident of the splendid quality and quantity of the colony's iron resources, and the year after the settlement of Jamestown seven tons of iron were smelted in Bristol from Virginia ore. Twelve years later, in 1620, at a convenient waterfall, sixty-five miles up the James, an iron furnace was begun: but the roseate hopes of its builders did not result in the smelting of iron. Disease, death, delay, financial difficulties, and, finally, the Indian massacre of 1622, caused the abandonment of the enterprise. The first iron smelted in America was made in Massachusetts,

In 1644 John Winthrop, Jr., son of the governor, began the building of iron works, having previously gone to England and formed "The Company of Undertakers for the Iron Works," with a capital of £1,000 sterling. The next year he was making iron at Lynn, and three years later the output was seven tons a week. The company soon got into bad repute because of the devastation of the adjacent forests, and lawsuits resulted from the overflowing of their dam, from which came their power. Forty years later the plant was entirely closed down. It was, however, followed soon after its origin by other works, and for the century following 1620 Massachusetts was the chief iron maker among the colonies.

In 1658 some of the Winthrop associates founded iron works in New Haven, Conn., and shortly after that works were built in Rhode Island; but the other New England States made no iron until the eighteenth century.

It should be noted that most of the early New England works were bloomaries, although there were some blast furnaces making castings. In 1784 there were seventy-six iron works in Massachusetts, but many of them were small. For a century Massachusetts iron was made from the bog ore from glacial lakes and ponds, which so

abound, particularly in the eastern part of that State. Every two decades the crop was gathered afresh and together with the marine shells from the neighboring sea was burned in charcoal forges. Some of these early works were abandoned because of the exhaustion of the adjacent supply of wood. In 1804 one of these furnaces, known as the Federal furnace, was declared by its owner to be the finest furnace known. He stated that it had two bellows 22 feet long by 4 feet wide, which were operated by a water wheel 25 feet in diameter. It was at that time chiefly depending upon bog ore brought by vessel from Egg Harbor, N. J. This ore, having thirty to forty per cent iron, cost $6.50 per ton delivered. Local bog ore yielded from twenty to thirty per cent, and cost $6 at the furnace, while a poor grade of bog ore, yielding but eighteen per cent, was bought by some forges at $4 per ton delivered.

About 1750 a new iron field was opened in the western part of Massachusetts, in the older ore deposits of Berkshire Hills, and in 1765 there was here a famous furnace 28 feet in height. Adjacent to the Berkshire region was Litchfield County, Conn., which began to produce iron about the same time, and for a century was a famous iron district. A noted furnace here

required three tons of ore and 250 bushels of charcoal to make a ton of iron, and made 2½ tons of iron per day. In 1800 this county had 50 bloomary forges, and throughout the middle and latter part of the eighteenth century this type of iron works was very common upon the streams flowing into Long Island Sound from the north.

It was not until 1775 that iron was made in Vermont, and the famous Champlain district was not opened until 1801.

New York seems to have been a slow State in the development of iron works, the beginning being in 1740, in the region east of the Hudson, which was really a part of the Massachusetts-Connecticut field. In 1752 the Stirling forges in Orange County were established, and soon became one of the leading works in the country. Here was made the famous chain that was stretched across the Hudson at West Point by the Americans to block the passage of the British ships. Here, also, the anchors of the first American war vessels were forged. By the end of the eighteenth century this plant was producing 2,000 tons of iron per year.

New Jersey duplicated the history of Massachusetts in the use of bog ores. An iron maker from Massachusetts settled in the low-lying part

of the State, near New York Bay, and started up the first establishment in 1676. In the middle of the eighteenth century, Burlington, on the Delaware, and other places to the east of it (Mount Holly and Egg Harbor), were using bog ore from the numerous ponds of central Jersey. The pine forests of this State furnished good charcoal, and this section had many plants in the quarter century before the Revolution. The works at Burlington made shot for the Revolutionary cannon, as did other works in northern Jersey, at Mount Hope and Hibernia, which in 1777 were the only blast furnaces operating in the State. An act of the Legislature exempted their workmen from military service because of the importance of the work in supplying ammunition for Washington's artillery.

The north Jersey ore field, comprising the older deposits of magnetic ore, was making a little iron as early as 1710, and between 1725 and 1770 this district, with its good ores, its wooded hills, and rapid streams for power, was quite an important center. It enjoyed a distinct advantage in being near the New York market.

The State of Pennsylvania, now the admitted leader of all the country and of the world in

the making of iron and steel, was also prominent in the colonial period, but it was nearly three-quarters of a century behind Massachusetts in getting started. It is probable that 1716 is the date of the first iron making in that colony, and by 1734 there were about twenty bloomaries and other iron works near Philadelphia.

Between 1730 and 1750 the industry spread to the north and west, into Montgomery, Bucks, Berks, Chester, Lancaster, and Lebanon counties. One of these plants, established in 1751, was the forge at Valley Creek, which became famous as Washington's headquarters under the name of Valley Forge.

The Pennsylvania industry differed from that of the other colonies by changing shortly after 1730 almost entirely from the use of the bloomary forges to furnaces, which made pig iron, to be later refined into higher grades or made into castings. In another respect, also, the Pennsylvania iron works were unique at this time—that is, in the prohibition of the sale of intoxicating liquors in their vicinity. In 1723 the iron makers sought of the Legislature and received its permission to have prohibition for twelve years within three miles of a blast furnace, unless otherwise requested by the ironmasters. This restriction worked so beneficently in the

cure of labor difficulties that it was asked for and regranted in 1735.

During the first quarter century of iron making in Pennsylvania the industry had spread quite generally in the region between the Delaware and the Susquehanna, and northward to the mountains. Near midcentury it crossed the Susquehanna, with establishments at York in 1756, and six years later iron was being made in Cumberland County. In 1767 the Juniata Valley, the chief tributary of the Susquehanna, was the scene of new blast furnaces. Although the colony was late in starting, there were built within it sixty furnaces in the sixty years intervening between the founding of the iron industry and the Declaration of Independence.

In 1759 a foreign observer reported that the Pennsylvania iron industry was more advanced than that of any other colony. At the Reading, Cornwall, and Warwick furnaces, which were 32 feet in height, the weekly output was 25 to 30 tons of iron, an output greatly exceeding that of the small bloomaries, which were to be found in most of the other colonies at that time. A typical iron works of this period was the Martic furnace and forge on Pequea Creek, among the Susquehanna hills of western Lancaster County.

This property consisted of 3,400 acres, nearly all woodland, for the supplying of its own charcoal. It had two forges for the working up of its own product, and its remote location enabled it to remain undisturbed and serve the country well in making muskets and other supplies for the Continental Army.

It was the almost universal custom in 1760 for the Pennsylvania iron works to close down during the heat of the summer. Doubtless the shortage of water power at this season was a contributing cause. Water was the universal power in this as in the other colonies, the steam engine not being introduced until after 1800, although it had been in use half a century earlier in the British iron works. In 1760 most of the Pennsylvania iron works were within a forty-mile radius of Philadelphia, although, as above mentioned, there were several beyond Susquehanna, and there were several erected beyond the Alleghenys late in the eighteenth century. In 1778 the first plant began work in the Wyoming Valley.

Delaware and Maryland took a less conspicuous part in the colonial iron manufacture. Delaware began in 1726, and other plants soon followed, but they were not of the largest type, owing to the rather meager ore deposits of this

State. Even as late as 1810 it had only forges, without a single furnace.

Maryland, which had begun making iron in 1716, exported three tons of bar iron to England in 1718, but was the next year without works, and the Legislature offered 100 acres of land to anyone who would start making iron within the State. There were soon other works established, and like their predecessors they were located around the head of Chesapeake Bay, particularly at the Northeast, which during the colonial period was the center of Maryland's iron manufacture. In 1761 the eight furnaces in the State had a capacity of 2,500 tons of iron per year, and the ten forges increased this by 600 tons. In the decade preceding the Revolution there were scattered plants in the piedmont counties of Frederick and Carroll. The Hagerstown Valley of western Maryland was also the scene of iron making before the Revolution, and the first cannon cast in the State of Maryland was made for the Continental Army on a branch of Antietam Creek near Hagerstown.

Virginia, despite her early attempt in 1620, did not succeed in making iron until ninety-six years thereafter, and by 1732 there were only four furnaces in the State and no forges. Her iron makers then boasted, however, that their

industry was carried on in the most modern method of the time. The beginnings of iron making were in the tide-water district. The first important plant was located on the peninsula between the Rappahannock and the Potomac, and according to Colonel Spotswood and Mr. Chiswell, who were pioneers here, the equipment for the beginning was rather large. "For one moderate furnace 4 square miles of woodland and 120 slaves were required. One furnace cost £700, ready for work; Mr. Chiswell's property cost £12,000, including furnace, 15,000 acres of land, the necessary cattle, 80 negroes, and the expense of making 1,200 tons of pig iron." Before 1760 there were plants in the Shenandoah Valley, and they are reported as having been numerous there before the Revolution. This section, with its many outcrops of limestone in contact with other rocks, gave many ore deposits easily accessible.

North Carolina was exporting to Great Britain as early as 1728 and 1729, and continued to do so at intervals until the Revolution. Apparently this metal was made in the eastern part of the State from bog ore. The neighboring State of South Carolina was very slow in the beginning of iron manufacture, the first being in 1772, but the forge was promptly destroyed by the Loyal-

ists upon the outbreak of the Revolutionary War. In 1816 there were only nine bloomaries in four counties. Georgia made no iron in the colonial period, and established its first bloomary in the coast district in 1790.

One of the most interesting colonial iron districts was that in the southern extension of the great valley and the neighboring Appalachian Mountains. The great valley running from Harrisburg, past Hagerstown, thence along the drainage systems of the Shenandoah, James, and Roanoke, was the avenue of entrance for settlers into Kentucky, Tennessee, and western North Carolina. There was a large emigration along this route at the close of the Revolutionary War, and the southwestern counties of Virginia had several iron works erected within their confines during the last decade of the eighteenth century. In 1791 the Bourbon furnace, one of the pioneer iron works of the Mississippi Valley, was established in Bath County, Ky. This Bourbon furnace was built so nearly on the frontier that the workmen who constructed it were constantly under guard to protect them from the Indians. The plant was, nevertheless, of the best design, producing three tons per day. It served a great need in that remote commonwealth, where the commodities of import were

received from Pittsburg, whither they had been carried in wagons over the Appalachian Mountains at great cost. The pots and kettles and blacksmith iron of the Bourbon furnace had therefore a wide market throughout the settlements of Kentucky. They were later floated down the stream to Cincinnati and Louisville. In 1810 contracts for artillery supplies were made with the United States Government, and in December, 1815, General Jackson worked his historic destruction of the British at New Orleans with cannon ball, grapeshot, and chain shot from this Kentucky furnace.

About the same time furnaces were erected in the valleys of western North Carolina; and in 1790 a plant was established in east Tennessee. This plant, which was located at the junction of the forks of the Holston River, had a rather surprising ability of shipping iron by the use of twenty-five-ton boats to the lower settlements, and even to New Orleans. The journey down the Tennessee River was a long one, but scarcely a thousand miles, as described by a writer of that day.

This brief sketch of iron manufacture in the United States shows that when George Washington became President of the country iron was being made in practically every State; in-

deed, in George Washington's administration there were many more iron districts than in that of Theodore Roosevelt, and iron making was so widespread because it was a local industry of small extent.

CHAPTER IV

THE ANTHRACITE EPOCH

The fuel required for the smelting of iron must burn very easily, must furnish great heat, and must be so physically hard as to bear up the burden of the ore that lies upon it; otherwise, it may crush down the fuel and smother the fire. Charcoal is an ideal fuel, if it can be had, and where it has been found in sufficient abundance it has met all needs. But no important iron district can grow enough wood to supply its furnaces with charcoal, and consequently the charcoal industry has always been short-lived or insignificant in any particular locality.

England was far ahead of America in the development of substitutes for charcoal. To these expedients she was driven. Before the settlement of America the people in some parts of England were crying out because of the forest devastation wrought by the coal burner, and the consequent necessity for a substitute led to the invention of a method of making iron with coal. Bituminous coal itself is unsuitable, because in

burning it melts down into a soft mass and chokes the fire. In the modified form of coke, however, Darby succeeded (1740), and by the end of the eighteenth century the use of charcoal as iron fuel had been almost entirely abandoned by Great Britain. In addition to the above stated reasons why Great Britain so early took her iron industry over on a coal basis, it should be pointed out that there were abundant supplies of coal and iron lying near each other; the British people had been using coal for at least two hundred years, and were well acquainted with it.

In America this history was not duplicated for many decades. For nearly half a century after England had abandoned charcoal, America used nothing else. Our fuel supply and other conditions were too radically different. Most of the country was still covered with virgin forests, whose removal was required by the progress of agriculture. The forest was cut to make new fields for the settler, there was no market for his timber, it was too heavy to carry many miles, and the clearer of the forest rejoiced that he could burn his heavy logs into light charcoal that could easily go miles to market. The fuel supply was therefore abundant in practically all localities at a time when Eng-

land's populace wailed and lamented over their bare hills, and legislated against the charcoal burner. In America, the distance between the known coal fields and the iron-making centers was great, and transportation of coal to iron or iron to coal was almost impossible, except in a few favored localities. In England, they were side by side. The manufacture of coke was an art not well known in this country, and some of the first coal with which the experiments were tried produced an inferior article. Further than this, the iron users were prejudiced, and not unnaturally, in favor of charcoal iron, which to this day has not been excelled. A prejudice, it should not be overlooked, is one of the hardest things for a business to combat.

It was therefore quite natural that the Pennsylvania Society for the Promotion of Internal Improvement should write to its European agent in 1825 the following unflattering account of the iron situation:

No improvements have been made here in it within the last thirty years, and the use of bituminous and anthracite coal in our furnaces is absolutely and entirely unknown. Attempts, and of the most costly kind, have been made to use the coal of the western part of our State in the production of iron. Furnaces have been constructed according to the plan said to be

adopted in Wales and elsewhere; persons claiming experience in the business have been employed; but all has been unsuccessful.

Accompanying the lack of advance in technical knowledge there had been little economic change in the iron industry of this country in the fifty or sixty years following its independence. Charcoal furnaces and forges were still used, and they combined to make the same scattered industry that had prevailed in the preceding century. It extended from Massachusetts, through southern and western New England, to Lake Champlain, down through the Berkshires and the New Jersey hills, all through Pennsylvania, both east and west, and throughout the Atlantic plain, to Carolina, Georgia, and Alabama. Iron plants were, however, not so numerous in the Southern States as they were in the North. In 1830 Berks County, Pennsylvania, had 11 furnaces and 24 forges. In 1840 Franklin County had 8 furnaces, 11 forges and rolling mills. Cumberland County had 6 furnaces and 5 forges. Bedford County, including Fulton, had 9 furnaces and 2 forges. By 1856 Virginia had erected 88 furnaces in 31 counties, and 59 forges in 29 counties, and more than half were in operation in that year. The

industry had also crossed the Appalachian Mountains, and western Pennsylvania had made iron before 1800. In 1805 Fayette, one of the western counties, had 5 furnaces and 6 forges, and by 1840 they were numerous in the upper Ohio Valley, and were scattered throughout Ohio, Indiana, Illinois, and also in Missouri.

The reason for this widely scattered industry was due to the nature of iron making and to the conditions of trade and commerce of the country at that time. We were not a manufacturing people, and the chief consumers of iron were the blacksmiths, whose resounding shops stood at the crossroads in almost every township in the United States. This was before the extension of railroads, and transportation was difficult. It is hard for us who have been born, educated, and brought up after the epoch of the railway, the telegraph, and the daily paper to appreciate the isolated conditions existing in 1840. In practically all parts of the United States the conditions of transportation were, with the exception of an occasional turnpike, the same as in the last decade of the eighteenth century. At that time an observer reported that he had seen 500 pack horses at one time in Carlisle, Pa., going westward through the great valley loaded with merchandise. Part of this cargo

was bar iron, which was bent to fit the horse's back, and in the upturned ends barrels, kegs, and packages were hung. Thus loaded, the animals started off in trains, and in hilly districts the trails over which they went were at times so deeply washed that their packs came in contact with the ground. So universal was this method of transportation that when wagons were introduced the pack carriers considered that their rights had been invaded, and the wagon was not always a great financial improvement over the pack animal in long-distance transportation.

It is quite natural, owing to these conditions, that there should have been a local demand for a great number of small furnaces; and in response to this demand furnaces continued to thrive in the remote agricultural settlements in the valleys of New England and Virginia, and in fact in almost the whole settled part of the United States, each supplying the village blacksmiths in the small territory near to it.

It was a fortunate occurrence that the more concentrated iron industry, made possible through the use of anthracite coal, had as its necessary complement the railroad. This new opening of markets and the use of the new fuel came almost simultaneously, and for the

first time in American history we were able to transport the product of the most favored locality to the great markets. Anthracite coal was a boon to iron makers. It possesses the desired fuel qualities for iron making, being pure, burning with great heat, and bearing the burden of the ore upon it. Unfortunately for its introduction, it was so hard and so difficult to burn that the early attempts at iron making were a long series of failures. As early as 1807 the Lehigh Coal Mining Company leased a tract of land of 200 acres for a period of twenty-one years to Messrs. Butler and Rowland, who had a patent right to make anthracite iron, and were granted by the coal company the privilege of mining both coal and iron ore without charge for twenty-one years. But their scheme proved to be only a hope. Nothing came of it, and their lease lapsed seven years later.

The year 1812 marks the first actual introduction of anthracite coal into iron works although it was scarcely a profitable venture. Of the first shipment of seven wagonloads to Philadelphia, two loads were sold at cost of transportation, and the others given away because there were no purchasers. According to the story of some chroniclers, attempts of one of the purchasers to make fire in the heating fur-

nace of the rolling mills at the Falls of Schuylkill, now Philadelphia, resulted in a half day of disappointing labor. It would not kindle and the workmen condemned it in disgust, slammed the furnace door, and went to dinner. This gave the anthracite the undisturbed time it needed for kindling, and upon the return of the disgruntled workmen, the furnace seethed at white heat, and anthracite was thus introduced to Philadelphia after it had brought its vendors into ill repute by causing them to be accused of trying to sell stones as fuel. By 1823 it was being used in rolling mills at Boston; in 1825 a Phenixville steam engineer first successfully used it under a boiler, and in 1827 it was used in the same plant to heat a puddling furnace.

In the meantime experimenters were constantly failing both in this country and abroad in their attempts to smelt iron successfully with anthracite. Most of these experimenters used a mixture of anthracite coal and charcoal; but this did not produce satisfactory results. The real trouble lay in the fact that it was practically impossible to make a fire burn fast enough when it was fed with cold air, and success only came with the introduction of the hot blast or the feeding of the fire with previously heated air. It is strange that the white men of West-

ern civilization were so long in discovering this simple device. Chroniclers report its use in a primitive form in the smelting furnaces of the natives of Peru centuries before. These metallurgists put glowing coals on the metal pipes that carried the air to their forges. The first American iron furnaces with hot blast had special ovens, burning anthracite coal, but they were soon heated with the flames from the furnace itself.

The first successful smelter of iron with anthracite was one Dr. Geissenhainer, a native of Germany, who spent his life in Pennsylvania and New York. His triumph, in September, 1836, was followed during the next four years by a number of attempts by various ironmasters who made small amounts of iron after his method. But these were trials rather than successes, for all were temporary, and none was followed up. It did not become a real industrial factor until 1840. On January 18th of that year a dinner was given to celebrate the fact that certain iron makers of Pottsville, Pa., had won a prize of $5,000 that had been offered by public-spirited citizens for the first continuous operation of a blast furnace for three months with anthracite coal only. The year 1840 thus becomes the beginning of an iron epoch in Amer-

ica. In that year there were six furnaces in Pennsylvania dependent entirely upon the new fuel. New Jersey had one the next year. In 1846 there were 42 anthracite furnaces in Pennsylvania and New Jersey with a capacity of 122,000 tons per year. This average of more than 3,000 tons per furnace, or 60 tons per week, shows that they were twice as large as the best charcoal furnaces of the preceding century. With knowledge concerning the art of using mineral fuel, the blast furnace had now a basis upon which to grow, as the fuel would bear any load that was put upon it. At this time, too, the blast became better and stronger through the substitution of engines for water-wheels for the running of the air pumps. In 1849 a turning point was reached in the iron industry, when the standard for iron quotations became a ton of anthracite iron rather than a ton of charcoal iron. In 1856 there were 121 anthracite furnaces in running order. Of these, Pennsylvania had 93, New York 14, Maryland 6, New Jersey 4, Massachusetts 3, and Connecticut 1. Charcoal was distanced, and henceforward kept the second or third place. In 1854 the two fuels had produced almost identically the same amount, about 340,000 tons. The next year anthracite was 40,000 tons ahead, and the strong boom

shortly thereafter in the anthracite iron made it reach 500,000 tons in 1860, or about double the charcoal-made supply. By 1880 anthracite iron was nearly 2,000,000 tons; but it is interesting to note that the charcoal iron had reached a half million tons, which was greatly more than in the period when anthracite was first introduced as a fuel, and fifty per cent more than at the time when the anthracite product first exceeded that of the charcoal. The reign of anthracite, however, was short; bituminous iron deposed it, and soon outstripped it in the race for statistical totals.

CHAPTER V

THE COKE EPOCH

THE kingship of anthracite was very short in the kingdom of iron. It was scarcely to have been expected that this coal, all located in such a small area of one State, and comprising such an insignificant fraction of our total coal resources, should have long continued to be the chief source of heat in the smelting of iron after men had once learned that mineral fuels of any sort had been adapted to the profitable making of iron.

The bituminous coal which underlies half of the State of Pennsylvania and areas in other States plenty large enough to make a good handful of European kingdoms was destined to overtake anthracite and place it even more definitely in the rear than it, in its turn, had done for the time-honored and age-long charcoal fuel. The surprising thing is that our bituminous coal resources, like our anthracite coal resources, remained so long unused in the face of successful practice for so many decades in England.

This disparity certainly could not have continued in any age but that of sailing vessels and the stagecoaches. With our present facility for exchanging ideas and commodities it would have been almost impossible for the English process to be so long limited to England. While the English iron maker had with alacrity seized upon coke in the middle of the eighteenth century, it was 1819 before we find out in Armstrong County, Pennsylvania, at the Bear Creek furnace, the first serious experiment with coke; and after making three tons of iron the furnace chilled so that the attempt was abandoned, and the familiar charcoal again taken up. Nor were other attempts at copying the English rapidly made, and even when attempted they were unsuccessful. In 1835, ninety-five years after the English success with coke, the Franklin Institute, of Philadelphia, offered a premium of a gold medal " to the person who shall manufacture in the United States the greatest quantity of iron from the ore during the year, using no other fuel than bituminous coal or coke, the quantity not to be less than twenty tons." It is quite an interesting commentary upon the state of the journals and the general communication of that time that this medal appears never to have been awarded, although in the

same year a furnace at Huntington, Pa., had succeeded in running a month on coke, and two years later one at Uniontown, in the southwestern corner of the State, made a hundred tons, and then returned to the old stand-by of charcoal. The period of most active experimentation, from 1836 to 1839, was identical with that which brought anthracite to the front. But the coke experiments, while often technically successful, were financially unsuccessful, probably the greatest of these failures being that of a Boston company, which erected a large furnace near Lockhaven, on the Susquehanna, and although they made between 1837 and 1839 3,500 tons of iron, it was so costly that the enterprise failed, with a loss of half a million dollars.

The first real success was not, as was the case with anthracite, a Pennsylvania achievement, but it was on Georges Creek, near Frostburg, in the mountains of western Maryland, that a large furnace was built especially for coke in 1837, and by 1839 it was successfully making 70 tons a week, and the success was permanent. The next year the Mount Savage Company, in the same vicinity, built two large coke furnaces. These successes, however, were rather a demonstration than the beginning of an epoch. Progress in coke-made iron was for a time exceed-

ingly slow. As late as 1849 there was not a single plant using it in the State of Pennsylvania. Many who tried it had failed, giving signal proof of the maxim sometimes attributed to Carnegie as one of his favorites that "pioneering doesn't pay."

In 1856 there were 21 coke-iron furnaces in Pennsylvania, and 3 in Maryland; but it was not until 1865 that any rapid strides in the coke-iron industry began. In that year only 100,000 tons of coke were used, but in fifteen more years the amount of coke consumed had increased over twentyfold.

During the period from 1840 to 1865 these two mineral fuels, anthracite and coke, were running side by side, with competition greatly in the favor of anthracite. There were several good reasons for this; one was the low cost of the anthracite coal. At the present time most people are acquainted with anthracite prices only as for a domestic fuel purchased from a coal combine which possesses an absolute monopoly and a perfect power to set the price at the highest figure the consumer will pay. In the middle of the nineteenth century it was otherwise. The coal producers were many, and they competed with each other in a desperate manner that put prices down to the bottom. Anthracite in

those days was easier to get. The great deposits were new. The best seams only were being worked. The chambers from which it was brought were near the surface, and its extraction was easy. It therefore afforded a strong competition in price with any other kind of coal.

Another reason for the successful competition of anthracite lay in the fact that it possessed a geographic advantage in transportation. The most important mines were at the head of a railroad running steadily downgrade to tide water on the Delaware, at Philadelphia. A canal came down the Lehigh River to the upper Delaware and connected with the Delaware and Raritan Canal, which passed from Trenton to New York. Thus, in a period when the railroads had reached no high efficiency, the iron industry in the anthracite district had the advantage of the cheapest kind of transportation to the sea and to all the great markets of the manufacturing East. Transportation conditions had changed during the period from 1865 to 1880, when coke-made coal took its great boom and experienced its twentyfold increase in less than as many years. The war was over. This was a period of great advancement in railway transportation. Western Pennsylvania, the center of the coke industry, was brought into con-

Row of Connellsville Coke Ovens Burning

nection with the East by good railroads; also with the Great Lakes and with the Mississippi

Valley. It further had at its disposal the potent influence of the Ohio River boats. There was then developed in western Pennsylvania a coal seam of most remarkable quality in the making of coke, one which had a signal influence upon the American iron industry, and, indeed, upon the iron industry of the world. This coal seam, with its chief mining center at Connellsville, has caused that town to be known wherever iron manufacture is talked or written about. Connellsville coke was the standard by which all other cokes were measured. It was sought by all iron makers who could reach it, and many who could not reach it failed because they could not. Upon the basis of Connellsville coke has arisen Pittsburg's greatness, and to the same cause we may attribute the decline of anthracite. For just twenty years, from 1855 to 1875, anthracite was in the lead. In the latter year it was eclipsed by coke made from bituminous coal, each having about 900,000 tons. Eight years later, in the prosperity of 1883, anthracite iron had doubled, and the coke-made output had more than trebled.

The geographic distribution of the iron industry during the past seventy-five years has been most varied, due to the fact that it has responded during that time to three distinct

influences. As explained above, during the charcoal epoch, it was made in almost every community where ore and charcoal could be found, because the transportation cost was so great that it could not profitably be carried great distances; and also because the amount required in every community was small, and a small plant, corresponding to the local grist mill or the local sawmill, could supply a community's need. In a country like the eastern United States that was everywhere forested and possessed numerous small deposits of iron ore, natural conditions favored the widest distribution of the industry.

With the coming of anthracite, while many of the small charcoal furnaces remained in the distant localities, the iron industry had for the first time a geographic emphasis. This was supplied by that section which was enabled to make iron in large quantities for export to the great consuming centers. This district was upon the highlands between the Delaware, the Schuylkill, and the Susquehanna valleys, and besides possessing all the anthracite, it is about equidistant and only a hundred miles from Philadelphia and New York. These advantages made possible the first leadership in American iron making and the development of the first great

shipping field. At this time the Schuylkill Valley stood high as the great iron-making center, but furnaces on the Susquehanna were favorably located, and northern New Jersey also lay as near the fields as did southeastern Pennsylvania, while southern New York was on the continued arc of the same circle that, having its center at the anthracite mines, passed through southeastern Pennsylvania, Philadelphia, and north Jersey.

Then came the coke epoch. Again the basis for geographic emphasis changed, and with it the iron industry slowly crawled over the Appalachian Mountains into the drainage basin of the upper Ohio. Coke-made iron before 1890 meant almost entirely western Pennsylvania iron. Between 1873 and 1883, while anthracite iron increased fifty per cent, and charcoal iron remained stationary, bituminous iron increased one hundred and seventy-five per cent, and of the iron included in these later anthracite figures at least a half was smelted with a mixture of bituminous coal.

Pittsburg, which has gradually become the capital of the iron world, has become so because of the wonderful effect of its location with regard to resources and transport. It lies in a high rolling country full of deep, sharp valleys,

which can be crossed by railroads only at the expense of heavy grades, and therefore great cost in building and in operation; consequently, the railroads all run down streams, and all the streams gather into the rivers which mingle their waters at Pittsburg. These rolling hills flanking all these streams have in their summits, most easily accessible, the wonderful seam of Pittsburg coal. Natural gas hisses from the orifices in the rocks. Forty miles up the navigable Monongahela is Connellsville, capital of the world of coke. In many of the valleys is the limestone, so greatly needed in the making of iron, and reasonably abundant supplies of iron ore are also in the district. Pittsburg could not help becoming the iron center, and when, in the period of the early eighties, the supply of ore began to be derived from the upper Lake Superior region and transportation lines were organized to carry it, we had laid the basis for the iron developments which have culminated in the astonishing production of recent years, which has been one of the most spectacular occurrences in all industrial history, and which has held the attention of the whole world as probably no other purely industrial achievement has ever done. The stream of ore from Superior, and of coke from Connellsville, borne on the wheels

of gravity down the valleys which meet at Pittsburg, have been fed into the roaring furnaces that have made Pittsburg the "Smoky City," and given it an iron output which no prophet of 1850 would have believed possible for a continent.

Pittsburg possesses an unprecedented and almost undreamed of iron production because transportation made possible the assembling of the widely scattered raw materials and the marketing of the product over hundreds of thousands of square miles. In interesting contrast to this is the fact that after Pittsburg had become the leader of the iron industry of the country, there still continued in the southern Appalachia a local iron industry which had through all the progress of smelting and transportation remained unchanged. As late as 1883 there were in northwestern North Carolina two dozen forges of the old Catalan type, and another dozen in the adjacent counties of Tennessee. This was a pioneer iron district and a good one in the last decade of the eighteenth century when the whole country was backwoods. As the hardy pioneers of Virginia pushed westward, some of them went into the mountain valleys that had no outlet to the west for the aspiring emigrant. Their descendants are there yet, and there has

been no outlet anywhere for the sale of commodities or the import of commodities or of new ideas. Here, where the frontiersman of 1790 got caught in the wilderness, from which he could not escape or ship his produce, he could not change his industrial condition. Some one has lately had the insight to name him our "contemporary ancestor," which, indeed, he is, unchanged from the Revolutionary period. Here, ninety years after the first charcoal forges were established, the type of furnace was absolutely unchanged. Its blast was still operated by the primitive trompe; they were fitfully operated according to the needs of the local blacksmith and as the supply of water in the fluctuating mountain stream permitted. The name of "thundergust forges" was not inappropriately applied to them, because of their operation immediately after a shower had filled the streams. The bar iron thus produced was at that time used as legal tender in Johnson and Carter counties, Tenn., where the natives brought it to the little country store and exchanged it for such coffee, sugar, and calico as they got. The merchant then sent the bars of iron which he had thus secured on to the markets at Knoxville, Bristol, and other points which connected with the outside world.

The last twenty-five years have caused this wilderness to be invaded on all sides by the railway, the symbol of modern industry and the distributer of products of centralized manufacture. Many of the formerly unbridged streams are bridged and some of the closed valleys have been opened up; but it is doubtful if yet the Catalan forges in the remote hills are all cold. Certainly some of them have operated in the twentieth century.

At the same time that the primitive Catalan forge held sway among the Appalachian moonshiners, a modified form of the same device was holding its own in the Lake Champlain district. Here the old Catalan had been improved by the Americans, until it deserved the name of the American bloomary forge. The blast was heated, and while it used charcoal the resulting blooms were 300 to 400 pounds in weight, the quality excellent, and it was sold for special uses. The status of this industry is shown by the surprising fact that between the years 1875 and 1882 its output increased from 23,000 to 43,000 tons; thus nearly doubling in the face of the triumph in production of Pittsburg coke-made iron.

During the last twenty-five years the Champlain district has shifted to a coke basis, and

there have arisen two other new iron centers, one in Alabama, the other in Colorado. In the making of iron it is usually necessary for the fuel or the ore to be transported to some common meeting place, and in the working out of this problem of transportation the location of the iron industry has usually responded to the motto that " the ore goes to the fuel," an example of this being the great movement of Lake Superior ores to the western Pennsylvania coal fields. But it is not, however, a maxim of absolute sway. The question is rather complex, and is to be answered by weighing various freight factors involved in getting the ore and the fuel to the furnace and the finished product to the market. It is, therefore, a triangular problem, and it sometimes works out to the moving of the fuel rather than of the ore. Examples of this are afforded by the present industry on Lake Champlain and in northern New Jersey. Here are ore fields of excellent character; in both fields iron is being made with coke from western Pennsylvania. The reason they can afford to break the maxim and carry the fuel to the ore is found by noting the disposition of the finished product. It goes to New England and the East, and the fuel is therefore moving toward the final market of iron. In the same

way, in the Pittsburg region, the ore from Superior has practically been traveling toward its market, which was in Pittsburg and the cities of the East. Latterly there has arisen a new iron industry on Lake Superior near that ore field. This industry is of comparatively small extent, and although it uses eastern fuel, it will doubtless grow, because the market will be found in the rapidly developing Northwest.

The Alabama iron district is one of the cheapest, if not the cheapest iron district, in the entire world. It possesses a phenomenal natural equipment. Jutting out of the hillsides that flank one side of the broad open valley are thick deposits of iron ore. On the other side of the valley are the coal mines and the coke ovens, and the limestone is at hand. Instead of carrying ore a thousand miles, as at Pittsburg or the English furnaces, or fuel 600 miles, as at Lake Champlain, the raw materials for these southern furnaces are shifted across the valley by switching engines, and the local supply of cheap black labor helps to give a wonderfully low cost. The Colorado field has local ore and local coal not far away, and while costs are higher than in any of the great eastern iron districts, the furnaces here have the advantage of a local market which can be supplied from rival fields

only by metal upon which a freight of one to two thousand miles has been levied. As a result, the Colorado furnaces have in that State and in adjacent Rocky Mountain regions a wide field in which they have transportation advantage over all rivals. This is, however, a district of sparse population, a whole State sometimes not equaling a big ward in some of the eastern cities. The iron product of Colorado is therefore comparatively insignificant in the country's total production.

The output of the Pittsburg furnaces is greater than ever and steadily growing; but the leadership of Pittsburg is declining, as shown by its decreasing proportion of the total output. There is a distinct movement of iron smelting toward the shores of the Great Lakes. As it now is, the coke and the ore are both put upon cars and unloaded at Pittsburg. By erecting a blast furnace on the shore of the lake, one handling of the ore can be avoided by simply extending the journey of the coke across to the lake, where it is dumped into the storage bins of a blast furnace whose ore bins are filled direct from an ore steamer. The production in Cleveland and other lake-shore points is consequently increasing more rapidly than in Pittsburg, although it is yet comparatively small.

The action of the Lackawanna Steel Company is illustrative of this point. This great company was a relic of the anthracite epoch, with its plant on a hill at Scranton, exactly over an anthracite mine. But the rising price of anthracite led the managers of this company to abandon the region, and, as a result of the search for a better location, they finally selected Buffalo, where their water-borne ores could be unloaded beside their furnaces, which are fed by coke from western Pennsylvania.

The supremacy of Connellsville coke is also on the wane. The coke is as good as ever, but there is another kind; and its appearance in the iron industry affords a good indication of the insecurity of any industry where men count upon a continued dependence upon existing industrial processes. Connellsville coke was and is vastly better than any other when made in the old-fashioned wasteful beehive oven, which pollutes the air and kills the vegetation of the surrounding community by belching forth in smoke, flame, and utter waste all of the volatile content of the coal. This has long been caught in the city gas works in the form of gas and tar, and now the process has spread. A new invention, the by-product coke oven, makes coke and saves the treasures which the Connellsville coke

burner wastes. By the old process no other coke was so strong as that of Connellsville, and therefore fit to bear the burden in the furnace, and many other coals possess enough of sulphur or other foreign substances to spoil the iron in the making. The way the by-product oven handles these difficulties is shown by the experience of the Cambria Steel Company at Johnstown. This plant had long been a slave to Connellsville, whence it brought its coke over the Pennsylvania Mountains. The small cubes of pyrites, or iron sulphide, in the otherwise good local coal rendered it unfit for blast-furnace coke. That coal is now ground up, washed like the material of a placer gold mine, the sulphur cubes extracted, the crushed and purified coal compressed into bricks, converted into coke in a by-product oven, the gas and tar saved, and the coal satisfactorily used in their blast furnaces.

Here we see a process which leads to the decentralization of the iron industry. Instead of being dependent upon one superior kind of coke, produced in one narrow territory, we are learning day by day how to make coke out of poorer and poorer coal over a wider and wider territory, and the area of successful blast furnaces of the most modern type is again spreading. There is no likelihood, however, of smelters of

this type ever going into the geographic odd corners sought out by the charcoal forges of a century ago.

Iron has at times been made directly from coals other than anthracite, but this has not been an important factor in iron production. It is claimed that during the Revolutionary War a furnace six miles from Richmond, Va., smelted iron from coal produced in Chesterfield County, Va. This was apparently a war emergency, and the use of coal as an industrial factor had its real beginning in 1845 in eastern Ohio. The coal of Shenango and Mahoning valleys, which has at times been called semi-anthracite, but has latterly been classed as bituminous, is locally known as " splint " coal, and possesses rare blast-furnace qualities. In 1856 the district of these two valleys had six blast furnaces in Pennsylvania and thirteen in Ohio, but it has declined rather than advanced as a factor in iron making. Coal of this character is unusual, the only other district of importance being that near Glasgow, Scotland, where it has also been used to some extent.

CHAPTER VI

THE NINETEENTH CENTURY LEADERSHIP OF GREAT BRITAIN IN IRON AND STEEL

England is our mother country; and she remained so in an industrial sense longer than in a political sense. In 1776 we declared our political equality, and in seven years had proved that our claims were founded in fact. It took another century and a little more for us to develop an iron industry which reached equality with that of Britain.

In the middle of the seventeenth century when the hardy Winthrop, backed by British capital, smelted the first American iron in Massachusetts, the mother country had three hundred furnaces and had been making iron for an unknown number of centuries. The next hundred years did not, however, increase the British leadership; for it was a period of decline in the iron industry of that country. This was the time when the demand for charcoal was causing a shortage of fuel supply in Great Britain, and that country was growing more and more dependent upon

Germany, until, by 1740, instead of 300 furnaces there were but 59, and they made only two fifths of the iron consumed in the country. At the same time the American iron industry was steadily increasing, exportations across the Atlantic being quite frequent, and the situation as it then stood promised that America might soon become an important factor in supplying Britain with iron. The then existing course of affairs was disturbed in an unpredictable way by invention, as has been so frequently and is so constantly the case in nearly all industries. Based upon the conditions of 1700, Britain was a declining factor, and the American colonies were a rising factor in the manufacture of iron; but the conditions of 1700, like the conditions of any other day, were not destined to last, but to melt away before improvement. England has shown a historical priority not only in the making of iron, and also a priority in the making of revolutionary inventions affecting that industry. In 1740 came the British invention of coke-smelted iron, as related in a previous chapter. Here a new vista opened before Great Britain. But it was not until the nineteenth century that her great leadership was made manifest. The forty-eight years after the discovery of coke smelting witnessed a gradual development of the British iron

industry near its coal fields, and the output increased from 17,000 tons to 68,000 tons. At this time the average output for the 85 furnaces in the country was 15½ tons per week.

In 1784 an Englishman named Henry Cort gave to the British iron industry a great push forward by his discovery of the puddling furnace and grooved rolls to assist in the purification of the iron. To fully understand the significance of these technical improvements a little explanation of iron making and purifying must be given. The old forge iron, which everywhere prevailed before the invention of the blast furnace and the making of cast iron, was never really melted. It was made into a viscous lump and taken from the forge to be hammered and reheated and refined in refinery forges or "finery" forges, until it was of the desired consistency and quality. Thus, by a single process, the ore was made into malleable iron, or iron that can be hammered. This was called direct iron, because made in one process. The blast furnace product is indirect in that the molten iron is run into molds and hardened into lumps, which are later purified and made into malleable iron. Cast iron was easier to make but much less pure than forge iron, because while melting in the furnace it absorbs impurities. The liquid

iron, just as water or any other liquid, is prone to absorb things with which it comes in contact. Water running over salt or dirt will absorb something, and molten iron running down through the fiery furnace absorbs carbon from the fuel. Cast iron can be counted upon to have, consequently, three and one half to four per cent of carbon. It will also have some silicon and some phosphorus. These foreign substances are the penalty that seems to be imposed in compensation for the cheapness of making cast iron. They render the product useless for many purposes. They make it brittle, and it cannot be forged either hot or cold; but, because of their presence, it is more easily melted.

Before Henry Cort made his puddling furnace this iron had to be purified in hearths and with hammers, laboriously, as had the old forge iron. Cort evolved the scheme of having a basin-like hearth, full of molten pig iron, across which rush the flames and burning gases from a fire behind a low partition. The chief objectionable element in cast iron is carbon, making it brittle, and as carbon is combustible, the flames gradually burn it out, the process being hastened by the stirring of the metal by a rake in the hands of the puddler, a laborer with a hot and arduous task. At last, as the carbon is burned

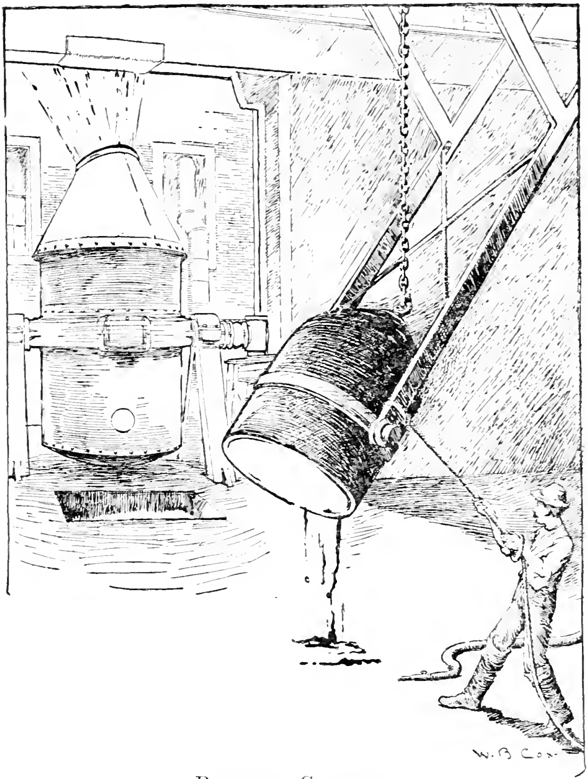
out, the fusibility of the iron decreases, and it rolls about, a viscous, spongy lump of tough, tenacious, red-hot iron of nearly pure composition and every pore filled with molten lava, which was the slag that floated on the top of the molten metal, and resulted from the combustion and from the partial destruction of the lining of the hearth. Except for the pores full of slag, this lump of iron from the puddler's rake was a great improvement over the old forge refining, and its further purification was promptly made easy by Cort's grooved rolls, which repeatedly squeezed the hot metal and ejected from it all the impurities many times faster than they could be hammered out.

Without these discoveries we could apparently never have had such fundamentally important pieces of metal as a railway iron or a ship's plate. The unaided hammer could not have achieved them. The puddle and the grooved roll closed the era of the blacksmith's supremacy and opened the era of machine manufacture. In seven years from 1784 Cort's processes had resulted in 50,000 tons of puddled iron per annum. In 1816 Samuel Baldwin Rogers made further great improvements by inventing a new lining for the puddling furnace, which greatly increased its efficiency.

In 1828 another profound change came into iron manufacture through the invention, by Mr. J. B. Neilson, also an Englishman, of a hot blast for the blast furnace. This invention increased the efficiency and decreased the cost of the process, but just why this should result scientists had not entirely agreed, or even that it should result at all. It was soon discovered, in practice, that the feeding of a blast furnace with air heated to 600 degrees Fahrenheit caused the same furnace to double its output, with no fuel increase. Here was a cheapening of cast iron to match the advantages that puddling and rolling had given to the manufacture of iron into malleable forms. The economic results of these inventions were seen in the greatly increased use of iron. For centuries the anchors of ships had been supported by heavy ropes, which were subject to being frayed by many possible accidental causes, and were subject to decay through the action of marine animals and plants. In the effort to preserve them they were kept scrupulously clean, as witnessed by the sailor's saying, "Six days thou shalt work and do all that thou art able, and on the seventh heave up and scrub the cable." After 1830 the heaving up ceased, for the shipmaster found it cheaper to replace his cable with the malleable iron chain.

The water pipes of great cities had been wooden logs, with holes bored in them, and carefully jointed together, with possibly an iron band or two on the ends; now iron pipe could be used. Gas, long known in the laboratory, could not be distributed through wooden pipes, but the cheapened iron made possible the great retorts for its manufacture and storage, and the pipes for its distribution throughout the cities. The railway had been used about British collieries for about two hundred and fifty years. As early as 1740 some one had suggested that iron be used in place of the wooden rails upon which the coal cars ran, and by 1780 cast iron began to be used slightly, but wood was continued in use until 1840. By 1820 there was a little malleable iron used for rails; but this, too, was sparingly applied, and it is more than a mere coincidence that the cheaper iron of the middle of the first half of the nineteenth century happened to come at the same time that the railway appeared. The railway had *demanded* it generations before. When this iron came the railway became important.

By the middle of the eighteenth century the field for the use of iron had so widened that the new uses to which it had been put brought it again into places where it was found unequal for



Bessemer Converter

the tasks required of it. It could not bear the strain; a stronger metal was needed. Again

consumption demanded progress in manufacture. The steel of that day was good, but far too costly. Just at this stage another revolution was brought about by the invention of Sir Henry Bessemer's new steel-making appliance, which bears his name. Than this there could be few better monuments to commemorate the career of a manufacturer. The value of his contribution will be better understood by noticing the process which it succeeded.

Steel is simply a mixture of iron with a small amount of carbon, very intimately and evenly associated in its mass. The carbon content of steel varies from .40 per cent to 1.50 per cent. Cast iron, therefore, differs from steel by having from three to ten times as much carbon in it. Wrought iron is iron with almost all the carbon worked out of it, and this approach to purity gives iron a toughness and pliability needed by the blacksmith in his work. Steel making is, therefore, a process of mixing carbon and iron in proper proportions. Inasmuch as it cannot be made satisfactorily in a puddling furnace, by reducing the carbon to a proper point and then stopping the furnace, it has been found necessary to burn the carbon all out, making wrought iron, and then working it back to steel by recarburizing under such conditions that the carbon

can be controlled. The process of puddling is itself expensive, and the wrought iron thus produced was, before Bessemer's day, made into the best steel by the costly process of cementation. In this way so-called blister steel was produced, by putting the wrought iron into a closed retort with charcoal (which is carbon), and then heating it to a red heat in the closed retort, where no air was available to burn up the carbon. The iron was allowed to remain in this red-hot carbon bath for days, the carbon penetrating the body of the iron at the rate of an eighth of an inch a day. When the iron had had time enough to be carbonized clear through, it was taken out, a rough, ragged bar, called blister steel. The slow addition of the carbon had given it a fine quality and great possibilities for fine work. It was now ready to be worked up into cutlery and the finest edged tools that man makes. There was nothing the matter with it, except its cost. Railroad men would think they had entered a new era if they could use it for rails. Fine cast steel, such as is used for great cannon or the shafts of steamships and many critical pieces in heavy machinery, is made by melting the blister steel in a crucible and then casting it. But the cost of all this work made a metal so high-priced that for the larger and cheaper industrial uses it was out of the

question. Man has never seen the time when his industry could afford to use a cast-steel rail or a cast-steel bridge or a cast-steel building.

Nevertheless, the industries of 1850 demanded cheap steel. Bessemer gave it by the profoundly important and simple device bearing his name, patented in 1855 and 1856, and finally successful in 1858. Instead of the puddler raking for hours his little puddle of iron into a viscous ball, later to soak for days in the charcoal bath to be recarbonized, Bessemer ran tons of molten iron into a great pear-shaped retort, and through holes in the bottom air, under pressure, was blown. The oxygen of the air united with the carbon in the molten iron, and the heat of this burning made in the retort a roaring fire, generating enough heat to keep the iron hot and to make it hotter. Sometimes it became too hot and had to be cooled by steam or masses of cold iron thrown into it. In twenty minutes this air blast had burned the carbon out of many tons of metal, and the iron now having the composition of wrought iron is raised to steel by having thrown into it spiegel iron, or ferro manganese, an alloy. Both are rich in manganese and carbon. As the iron content of the Bessemer converter is known and the content of the spiegel iron is known, the carbon in the steel is under perfect

control. The workman watching the flames cuts off the blast at the moment when the changing color tells him the carbon is gone. The carbon of the added material makes steel, and the manganese gives to the steel a toughness needed to make it stand the strain of being rolled into desired shapes while red-hot, without breaking.

This invention, it should be noted, like the two others mentioned in this chapter, was brought about in England, but through the coöperation of gentlemen, some of whom were not natives of England. Here is the real beginning of the modern period in iron and steel making. It is Bessemer's steel that has made possible the thousand new uses for that metal and the tremendous increase in iron manufacture that has marked the forty-nine years since Bessemer's success, at the risk of his life, mid the flying showers of molten metal that were ejected from his experimental converters.

England has had scientific progress as the basis for her nineteenth century leadership, and she has had peace. There has been no war whatever in England during the period since the discovery of coke-made iron, and upon every battlefield of the nineteenth century have roared the guns of English manufacture. The wars of other countries have been England's market;

and while the industries of the belligerents have stood still, England has forged iron with redoubled speed, at the same time making extra profits from the enforced purchases of her idle rivals. This was as true with the United States as with the Continental countries, and more so, because of the greater length of our Civil War, which absorbed the attention of the whole American people for four full years, during which time England was firmly establishing the Bessemer process and getting herself in a better position to supply the United States in the period of peace which followed the Civil War. We were at that time profoundly dependent upon England. The succeeding boom in railroad building was supported by her railroad iron. As much as one fifth of the British iron product of 1870 was sent to this country, and even in 1880 our total pig iron production of more than 4,000,000 tons was not quite half that of Great Britain. Germany was producing one third as much, and England justly claimed that she was "the workshop of the world." The leaders of the British iron industry and the British publicists were sitting complacently upon the pinnacle of their prosperity; they comfortably congratulated themselves upon their success, and looked down with benignant uncon-

cern upon an occasional carping prophet who peered across the Atlantic and across the Channel to see in America and Germany the possibilities of a growth which might take England's supremacy from her. And that supremacy has gone.

England's leadership at the end of the third quarter of the nineteenth century was naturally founded and securely held. In addition to the technical progress, peace and undisturbed industry, she had natural advantages for iron manufacture equaled by no other country. Four of her five great iron manufacturing industries were upon tide water, which gave easy access to the cheapest of transportation, that upon the sea; and within these iron districts there were other advantages no less important.

Middlesborough, located on the river Tees, on the northeast coast, was in the center of the ore region producing the famous Cleveland ores. A short distance to the north was Durham, the center of the best coke-making industry, and a short railroad haul brought these two materials together upon the banks of the Tees, whence the steamers could carry the finished product to all the coasts of England or to all the ports of the world. As the Cleveland ores declined in quantity, the furnaces of this district could change

over to the supply of Spanish ore, brought to them for a freight of $1.50 a ton. The favored location of these furnaces enabled them to make this change without any costly reorganization. With these favorable conditions it is plain why this iron district should have reached almost its maximum at a period when the iron and steel industries of Germany far up the Rhine, and Pittsburg, at the source of the Ohio, were in their infancy. Just across the narrow island of Great Britain on the west coast, upon the shores of Cumberland and west Lancashire, were the west-coast hematite ores, which had a great increase in the output between 1870 and 1880, reaching nearly 2,000,000 tons per annum, a large part of which was, when smelted, sent across the Atlantic to build the American railroads. These seaside furnaces were but a few hours in a coasting steamer from Liverpool, the great port for American trade. The returning grain ships often took the iron for ballast at almost no freight rate. This ore field is now also declining, and the works at Barrow-in-Furness have been almost stationary in their output for the last twenty years and are smelting greater and greater proportions of Spanish ore.

The third of these favored British iron dis-

tricts is that of West Scotland, near Glasgow, where iron has been important for one hundred and fifty years and where the making of iron has been particularly favored through the fact that the ore was blackband and containing in itself considerable carbon to help in the smelting. Further than this, the coal of Lanarkshire has the rare quality of being what is called " splint " coal, which can be put directly into a furnace for the smelting of iron without the intermediate cost of being made into coke. Here again was a district which could develop early, having its coal and its favorable ore almost side by side and both beside the sea. The maximum ore output of this district was reached in 1870 and has since been followed by a sharp decline, and the industry fed upon Spanish ore has not increased for forty years.

The history of the iron industry of South Wales, near the Welsh coal fields, is but a repetition of the others mentioned above, and England's leadership is plainly seen to be due to the fact that her advantages of peace, technical progress, abundant capital, and favorable natural resources enabled her to reach a stage of mature development some decades before the same results could be achieved in Germany, where political dissensions occupied the first two thirds of

the century, or in America, where in addition to the disturbance of Civil War, we had the whole vast continent to develop, and a comparatively sparse population with which to achieve the result.

CHAPTER VII

THE AGE OF STEEL

STEEL is a giant. It shows its giant qualities in almost every aspect. It is the strongest of our abundant metals; it has the most inconceivable variety of uses; from it we erect our most gigantic and imposing structures, our most enormous machines, our greatest ships. The archæologists and ethnologists have agreed that before the dawn of datable history a milestone of progress was marked when our half-naked ancestors had at enormous cost won a pound or so of iron per capita and begun the iron age of the historians. The keen analyst of the present, seeing our railways, our ships, our cannon, our sky scrapers, has erected another milestone, as he calls this The Age of Steel.

The close of the Civil War found the iron-making world in full possession of the Bessemer process of converting that metal into steel, and the United States and Europe as well were upon the verge of a great industrial and railroad expansion which made exceeding demands

for both iron and steel. This great boom, ending with the panic of 1873, was supported largely upon iron, but in the following decade the manufacture of steel advanced to the point where it was rapidly replacing iron in the most fundamental uses, such, for instance, as the railroad rail, steamship plate, and the railroad and highway bridge. From 1880 onward, the replacing of iron by steel and the expansion of the uses of steel have gone on with tremendous speed.

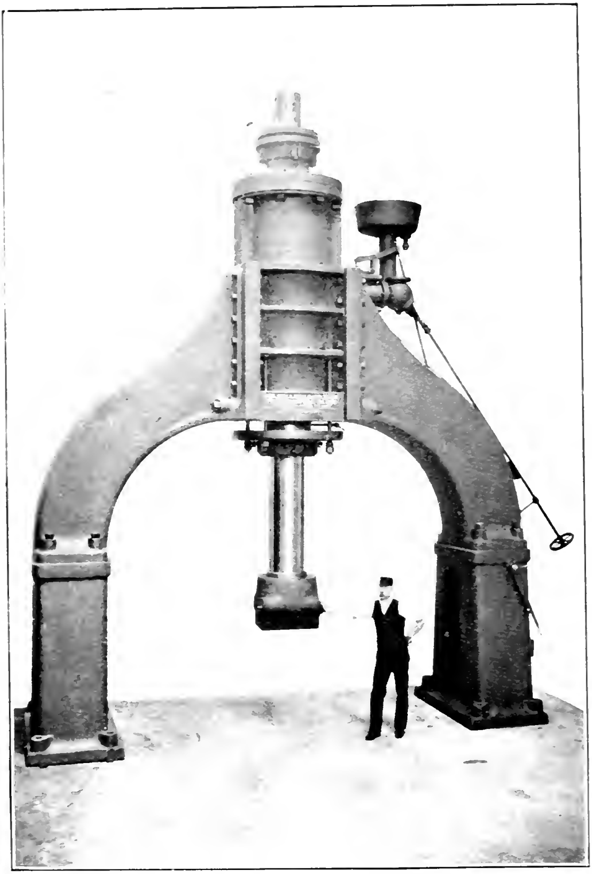
The variety of uses for this metal is absolutely beyond enumeration. It has resulted in a per capita increase of iron which when charted shows a rising curve that makes one wonder what we are coming to. Within the space of a generation we have increased our iron consumption fourfold, and each man, woman, and child among us is now responsible for the annual manufacture of several times his weight of iron, most of which is consumed in the form of steel.

Some of the more important of the uses which have resulted in this increase are worthy of consideration here, because they characterize the age of steel.

First of all, this is the age of power. Man has changed his economic and social conditions in that he has harnessed the forces of nature

to make them do his work. This is one of the most characteristic conditions of our modern civilization, and it should be noted that the harness for our power is, in every case, iron. Our main dependence, thus far, has been upon fuel, chiefly coal. This coal is burned upon an iron grate beneath an iron boiler, whence the gases and smoke are carried away into the open air through a tall iron smokestack. The power in the form of the steam generated in the boiler is kept imprisoned in iron pipes until released in the steel cylinder, where a steel piston drives forward a steel rod, which communicates the force to a steel fly wheel, turning on a steel shaft, and sending the power away to various places where man wishes to use it.

Portable engines, entirely made of iron and steel, are drawn about the country, or move themselves and carry loads. They traverse the highways to the farmer's dooryard and thresh his wheat, dig his well, and saw his wood. They penetrate the forests and send forth lumber; and in the level lands of the West they stand peacefully in a fence corner, and stretch an iron arm across broad acres, where through the shining hours of a single sun circuit they upturn broad acres to the cloudless sky and prepare them for the swiftly coming season, and even in



SEVEN-TON STEAM HAMMER.
The small handle at the right controls the blow.

the moonlight night of the rush season it labors tirelessly on while the displaced horse must rest and munch his hay. The engine eats and works at the same time, and when it rests it does not eat.

Other sources of power are also iron-harnessed. The dynamo rests upon a heavy iron frame and swings its iron arms and iron magnets through space, whence it mysteriously winds out power. The water wheel is of the hardest steel; it is fastened to the end of a long steel shaft, and is fed by water conducted in a penstock made of steel boiler plates.

The second of the great classes of iron uses is to be found in the machines that are driven by the power that man has learned to harness. Our coal and iron and copper are hoisted by strong engines lifting their burdens on steel cables. Our clothes are made in iron looms. The bricks of our houses are shaped in iron molds. The wood of our floors is ripped from a log of the primeval forest by a steel saw, and shaped and planed in a big steel planer. Our daily pabulum of print is thrown forth almost miraculously from a huge steel printing press, and the letters of the morning mail are clicked off on a steel typewriter, and posted in an iron letter box. The machines of the farmer are as

dependent upon steel as are those of his townsman brother. The multiform plows which dig up the earth are made of steel; so are the reaper and mowing machine and the planter, which glide over the surface. So, also, the hay fork which mechanically flings hay to the top of the barn, high overhead.

Transport is the third member of the mechanical trinity which goes with power and machines to make the present epoch. It is a well-known fact that for a long time the railways consumed half of man's total iron product. The locomotive is iron and steel from end to end and top to bottom; it runs upon rails of steel, steel-spiked to the sleepers beneath. It is probable that ere long we will be driven to use steel ties to which the rails shall be fastened. Streams and valleys are bridged with flying structures of steel. The wheels and running gear of the car have nearly always been made of iron and steel, and lately progress has gone farther and the freight car made of steel throughout has become a standard and the steel passenger coach is being rapidly introduced.

In the city, the street railway is a heavy consumer, and every improvement undertaken increases the demand for more steel. The elevated railway is nothing but a bridge spanning the city

in all directions, and the subway, its latest rival, is but a steel tunnel burrowing beneath the ground.

In the country, the erection of the trolley lines is now giving us a second set of railways, and even the poles are coming to be made of iron.

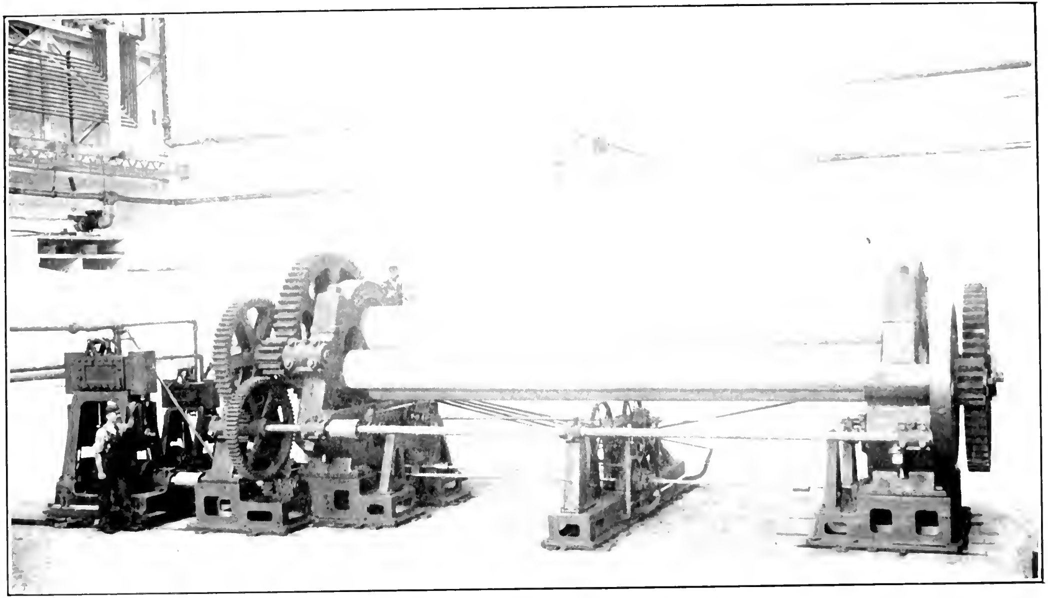
Half a century ago iron ships began to be common, a quarter of a century ago the ship-builder turned to steel, and now there is almost nothing else afloat upon the high seas. In the selection of material, the builder of the harbor lighter and the pleasure rowboat have followed the lead of the builder of battleships and ocean greyhounds.

Upon the land, we are having a steady increase of that stationary device for transportation, the pipe line, consuming annually tens of thousands of tons of metal as it reaches from the Atlantic to the Lakes, and the Lakes to the Gulf.

Our structures are becoming more and more dependent upon the products of the blast furnace and the steel mills. Our fathers contented themselves with brick and stone and wood. The limitation of wooden beams and the cheapness of Bessemer steel caused that material to be used in heavy structures in a limited way soon

after its introduction. As wood increased in value, knowledge of the use of steel increased and brought about the wider and wider introduction of this material in building, until we now see the modern sky scraper, in which wood is eliminated and steel is the absolute essential. In the old days of wooden structures, the wood demanded iron nails for its construction and gave a larger iron market than was furnished by such a masonry-using country as the continent of Europe. As the wood is eliminated its replacement to a greater and greater extent by steel tremendously expands the market for that metal. The shingle roof has been largely replaced by tin plate, chiefly composed of steel, or by galvanized steel, which is now gaining in favor. The improvements in the comfort of modern structures built for human occupation have centered themselves largely around plumbing, heating, and lighting, all of which ends have been achieved by the more and more extended introduction of pipes of steel and iron.

Not to be overlooked in the class of structures is the farmer's humble fence. The extravagant rail fence of the pioneer was gradually replaced by more economical wooden fences, and this within the past twenty-five years has almost uniformly given way to wire, which is stretched



POWER BENDING ROLLS FOR SHIP PLATES.

across the prairies of the West and the hills of the East in countless millions of miles, and as these then turn rusty, break down, and return to the elements, they must be continually replaced by more of the same kind, for there is no substitute yet in sight.

Modern industry, which supplies our wants as never before, uses iron and steel at every turn. The grosser industries of the oil refinery and the gas works show from afar their metal makeup. Even our food has dependence on metal. This is an age of canned goods, and the can which brings our Alaska salmon, East India pineapples, California asparagus, or Maryland peaches is made of tin plate. Minnesota wheat is pulverized into the world-famed flour by hard steel rollers; the baker turns it into a savory loaf in a metal oven. Whoever heard of a factory without machines of steel? The fine gentleman who parades the streets has, like the horse, steel nails in his shoes, and his tailor has fastened his clothes together with metal buttons, after having made the clothes through the agency of steel shears, needles, and sewing machines.

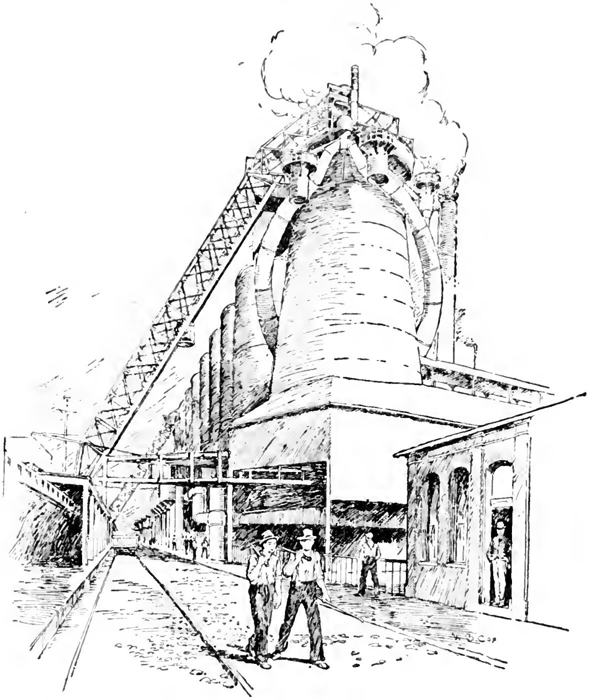
When emergency carries us to a hospital, the surgeon performs his wonders with instruments forged from the product of the steel crucible,

and when all is over, nails hold together the boards which form our coffin. If, perchance, we die abroad, we may return in a casket of steel.

Preceding, accompanying, and permitting this great increase in the uses of iron and steel, there has been development in its manufacture. The multitude of uses means that there must be many grades and kinds of iron and steel, and that the manufacturer must have perfect control of the product turned out in the various stages of its manufacture. This control he has.

It is therefore natural to expect that the blast furnace should be among the most thoroughly organized and most highly developed pieces of mechanism yet devised. It is certainly the most fearful of all man's creations, and considering the character of the process which goes on within it and its unapproachable heat, it is under a wonderful degree of control. At the present time, the best blast furnaces are a hundred feet high, consist of a great iron stack lined with some nonfusible material, and when in operation are filled from top to bottom with roaring fire. Into their fiery throats are fed alternately small carloads of coke and ore and limestone, and from the bottom there flows away at inter-

vals two molten streams—one the precious iron upon which our civilization rests; the other the



Two Modern Blast Furnaces with Row of Stoves Between

useless slag, to be got rid of in the cheapest possible way.

The unassisted fuel could not furnish enough heat to extract the iron from the ore without the presence of the limestone flux, which greatly reduces the melting temperature and helps get rid of impurities in the following manner.

All ore contains a certain amount of waste matter commonly called gangue. This is usually acid in its character, and the limestone having an opposite alkaline quality, called by the chemists a base, serves to neutralize it and make it melt at a lower temperature. Further than this, the melted limestone seems to have an affinity for dirt, similar to the affinity water has for salt, so that as the furnace gets hotter and hotter, the iron will drop to the bottom, and along with it flows the molten slag, which, fortunately, has the quality of being considerably lighter than the molten iron. Because of this convenient fact, the iron goes to the bottom, as milk goes below the cream in a pail, and can be drawn off through a low outlet after the slag has been drawn off at a higher outlet. The blast-furnace process in its entirety is not so simple as just described, for it is complicated by many refinements in which lie the fine points of the ironmaster's art. By controlling his ores, his fluxes and his furnace temperature, he controls the quality of his iron. All iron contains some

silicon, a substance of which common sand is a compound. The amount of silicon can be controlled in two ways: If the iron is smelted at a temperature of about 800° C., it will have about one per cent of silicon; 300° more heat will make it take three per cent of this impurity. As silicon is an acid substance and is neutralized by a base of limestone, an abundance of limestone slag will serve to dissolve the silicon and give low silicon iron, whereas a scarcity of limestone and much heat will give high silicon iron.

All iron insists upon absorbing a nearly uniform amount of carbon, amounting to three or four per cent, but this substance, fortunately, can be removed with ease and no great expense by the Bessemer process.

Sulphur, which is exceedingly injurious in iron and can never be removed unless it be done in the blast furnace, is best got rid of by having a limestone or basic slag and a very high temperature.

Phosphorus the smelting master cannot control. That which is in the ore and the coal goes into the iron. A small amount of it is practically ruinous to iron by making it brittle, and for a long time many otherwise good ores were useless until made available by recent discoveries.

It is thus evident that there are many kinds of cast iron, depending upon the amount of carbon, silicon, sulphur, and phosphorus, and the particular forms in which some of these occur.

The burning of this modern furnace takes place under a forced draught or air blast of from eight to twenty pounds per square inch. This pressure serves to drive the air upward through the hundred-foot mass which burns within the furnace. Otherwise, the fire would smother. The gas which results from the imperfect combustion within the furnace is a most valuable by-product and serves a valuable purpose in promoting the furnace operation, and sometimes leaves a product to sell. A part of the gas is taken to the boilers, where it generates power for the blowing engines. Another part of it is used in the so-called stoves to heat the air blast on its way to the furnaces. These stoves are almost as large as the furnace itself, and consist of great iron tanks filled with open work of brick. Each furnace has two or more stoves. The gas is led from the furnace to the first stove, where it is mixed with air and burned as it passes through the brickwork, which is thus heated to red heat, and when the desired temperature is attained, the gas is

turned into a second stove, while the air blast, passing through the first, is raised to a temperature of 800° to 1,100° C., at which red-hot temperature it enters the furnace to the great acceleration of the heat and combustion within. It is taken into the furnace near the bottom in pipes called " tuyeres," which are cooled by constantly flowing streams of water to prevent their melting. These economical uses of the blast-furnace gas are a factor in the cheap iron making of the present.

The pig iron resulting from the blast furnace is made into fine steel by the Cementation and Crucible processes, and into a cheaper steel by the Bessemer process, as previously explained. This process disposed of carbon and silicon with a flash and a roar, but, unfortunately, it could not make any use of iron containing phosphorus in appreciable quantities, because the purification which went on within this converter was limited to silicon and carbon only. Consequently, the first part of the Bessemer period started a great search for so-called Bessemer ores, or ores free enough from sulphur and phosphorus to make good steel by the revolutionizingly cheap process. After this had gone on for a score of years, we came, in 1878, upon another steel horizon through the discovery by

Messrs. Thomas and Gilchrist that by the simple device of putting into the Bessemer converter a limestone rather than a sandstone lining, the chemical state of the burden was changed and the basic limestone lining proceeded to extract the phosphorus from the iron. This so-called basic process made possible the use of ores high in phosphorus which hitherto had been of no avail, and the steel industry had a new road opened before it. But owing to the fact that the Bessemer converter keeps hot by the impurities it burns, it is necessary in this process to have about two per cent of phosphorus before there could be enough heat for the conversion of phosphatic iron. The result is that owing to the comparatively low phosphorus in the American ores, the basic Bessemer process has been limited to Europe, although many fine American ores have too much phosphorus to be classed as Bessemer ores.

Fortunately, these intermediate ores were not stranded uselessly between the two horns of a dilemma in phosphorus.

The principle involved in the basic process was applied to the open-hearth process, which is a much better process of making steel and one now rapidly superseding the Bessemer, particularly in America. The Bessemer process is

quick and cheap. There is a roar, a flying of sparks, and it is soon over. It is done so quickly that the product is not uniform and the recent great outcry against the steel rails is partly a condemnation of the Bessemer process. There is no time for testing the steel, and there is no time for slow work. It is like a pilot shooting rapids; he succeeds or he fails, but he doesn't try twice with the same boat. The rush of the Bessemer process arises from the necessity of keeping the iron molten through the burning of the silica, the carbon, or the phosphorus which it contains. When they are gone, it must be rapidly moved onward or it will "freeze," and the results, whatever they may be, are final.

The open-hearth process is a slower process with control. It is the invention of the Messrs. Siemens, who took out patents in 1856, the same year that Bessemer registered his invention. The process is really akin to puddling, in that there is a hearth of metal heated by gas flames beating over its surface. The process as first invented was not hot enough for success until its improvement eight years later by a Frenchman named Martin, who applied to it the so-called regenerating device, which is essentially the same as that above described in the blast-furnace stoves.

The flames, after passing over the steel-melting hearth, are carried through a brick framework which is heated, and after an interval the gas fuel is cut off and enters the furnace through the stove previously heated, while the waste gases heat a second stove on the other side of the furnace. The successful making of open-hearth steel in France in 1865 was followed by its introduction to the world at the Paris Exposition in 1867, where the American commissioners were much impressed, and brought it back to the United States, where it was tried in the same year. This process having a fuel supply entirely independent of the iron can go on as long as it is desired. It is under perfect control. Samples can be taken and examined. If too acid, limestone can be added; if it is too alkaline, silica can be added; if more carbon is needed, pig iron can be added; if less carbon is desired, scrap steel can be thrown in; if manganese is desired, ferromanganese can be added. If something does not oxidize fast enough, iron ore is thrown in, increasing the iron and enriching for a time the oxygen content. It is wonderfully like an old-fashioned cook who tastes her soup and adds a pinch of this, a bit of that, and a spoonful of the other, seasoning until the product just suits her. The open-

hearth process also uses up old scrap material, but it takes from eight to ten hours—a great disadvantage in comparison to the speed of Bessemer. This disadvantage makes a higher price, but with it goes a greater uniformity and strength which for the past forty years has caused this material to be used for boiler plates and other uses requiring steel of great reliability. For such pieces as railroad iron or structural girders, a small flaw which might be fatal to an engine boiler would make little difference, and therefore the cheaper Bessemer steel has been steadily used. Within the past year or two we have heard a great outcry because of the breakages of steel rails upon railroads and consequent railroad accidents. The number of these breakages has assumed alarming proportions, and the railroad men have declared that the steel makers have lowered the quality of their output. The steel makers have replied that the railways were by their heavy cars and greatly enlarged engines subjecting the tracks to strains before unknown, and strains which they could not stand. At the present time it is reported in various quarters that this demand of the railway managers is being answered by extensive preparations for the making of open-hearth rails, and the great trend of steel

making at the present time is toward the substitution of open hearth for the cheaper Bessemer product, as witnessed by the statistics of output.

The steel for the greater industries is shaped in a rolling mill. It comes from the Bessemer or open-hearth converter molded into a great billet like a piece of a large wooden beam, and this billet is carried red hot to a so-called soaking pit, where the licking tongues of a flame from a gas-fed fire keep it heated until it is ready to start on its journey through the mills. This soaking pit is the starting point of many roads through the mill. It goes off in one direction, and successive rollers squeeze it, crush it, and lengthen it into steel rails, in which form it emerges a thousand feet away. Other sets of rolls make the billet into flat beams for bridges or elevated railways. A third set of rolls, also starting near the soaking pits, send the product out of the distant door of the steel mill in the form of great flat plates to make the boiler of a locomotive, or a marine engine, or the sides of a steamship, and yet other sets of rollers will make square rods which finally pass under heavy shears and are chopped into pieces called billets or blooms. These pieces of steel are the raw material for other mills which may

make wire, nails, or manufacture steel of any other of a thousand forms. Some billets are as big as cord wood, some no larger than lead pencils—thus it passes out into the manifold world of manufacture.

CHAPTER VIII

THE TWENTIETH CENTURY SUPREMACY OF AMERICA

It has been pointed out in a previous chapter that the British iron industry greatly exceeded that of America in 1880. This was because geographical and industrial conditions in that country made possible the early maturity of the iron industry. It was ripe in 1880, but that of America, then in its infancy, has since made prodigious strides toward maturity. This continued and continuing great growth does not indicate that it has yet reached that point, but certain it is that we have far surpassed Great Britain or any other country. In 1880 Great Britain made $7\frac{3}{4}$ millions of tons of iron; we made less than 4, Germany less than 3. In 1905, a quarter of a century later, Great Britain made less than 10 million, Germany had passed her by a million tons, and the United States was approximately $2\frac{1}{2}$ times as great as her one-time peerless leader. At the present time, the State of Pennsylvania makes more iron than the whole British Empire.

The fact that British industry matured earlier than ours is significantly shown by noticing its almost stationary output since 1880, when ours has gone forward so rapidly. By taking averages for five years, between 1880 and 1884 and 1899 and 1903 it is shown that the pig-iron output in the United States increased 3.71 fold, Germany 2.68, Austria-Hungary 2.26, Belgium 1.47, France 1.35, Sweden 1.24, and Great Britain remained almost stationary at 1.08. In steel making the ratios are found more strikingly in America's favor, the United States having increased 8.21, Germany 7.35, Sweden 6.33, Austria Hungary 5.12, Belgium 4.46, France 3.52, and Great Britain 2.68. It is plain that England has not had her share of the increase which Levassaur has pointed out as a law of the iron-making world, namely, that "The production of pig iron has doubled almost every tenth year during the last fifty years." While the mature industry of England has slowly increased, that of America has rioted ahead until it outweighs that of both Great Britain and Germany, which are the only other iron countries of first-rate importance in the whole world.

This growth has come about from a number of good reasons. First, the American iron maker has had a great market. Here was a country

almost as large as all Europe, sparsely peopled, rapidly developing, with a population industrious, rich, and able to buy iron in large quantities, and imperatively needing it to develop their boundless resources. This vast market has been assured to the American iron and steel maker by a strong protective tariff which has always shielded him from the death-dealing competition which the more favorably located and equipped plants of Europe could have dealt twenty-five years ago. At the same time, mature little England, no larger than a couple of medium-sized American States, did not need much iron at home, and naturally bewailed the loss of the splendid American market which the American tariff closed to the limitation of the English furnace output.

We have had, and still have, unrivaled resources for the making of iron. Our ores are abundant and they are the richest that are being smelted in the world. Our coal fields are without a rival in the richness and abundance of their seams, their accessibility to the surface, and their good quality for the iron smelter. The necessary flux has been everywhere abundant. England has been compelled to use poorer and higher-priced materials. Further than this advantage in the staple materials, the Pittsburg

district has had and has diligently used a rich supply of fuel manna—the natural gas, unknown in England but spurting from the American earth and burning with a heat five times as great as its rival, coal gas, upon which the Englishman must depend.

But before these great resources of America could be utilized, a vast work has had to be done in the erection of plants and the establishing of means of transportation, for while our ores and coal are rich, it happens that those which are at the present time giving us our dominant position in the iron industry are situated 1,000 miles apart and present one of the most complicated transportation problems that modern industry has had to face. The list of our equipments has not been perfect, for while our material resources have been abundant, the human element, labor, has been proverbially scarce. The very richness of our resources in every respect has made such a wealth of opportunity for occupation that labor is and has been scarce and, as a result, highly paid. As a consequence, the American iron industry has been driven over to a machine basis, and its very success has arisen from the fact that the scarcity of labor has compelled the introduction of machinery which has surpassed the dreams of its inventors and given

us an iron industry different from that of any other country. It is due chiefly to the machinery and mechanical organization that America is now so far ahead of other iron-making countries.

The very speed of our increase has served to promote efficiency. The constant building of plants promotes plenty of experimentation, and new devices thus installed serve to show the inferiority of the old and to lead to its prompt abandonment in favor of the better. This apparent recklessness has been opposed by the policy prevalent in England, where it is common for an old equipment to be used until it is worn out rather than out of style. Traces of the same conservatism in the older districts of the eastern United States are distinctly visible. With the exception of the plants at Cornwall, Pa., Port Henry, N. Y., and Wharton, N. J., the plants east of the Alleghenies bear quite as much resemblance to those of England as they do to those of Pittsburg. It is in this latter district that the somersault reorganizations have taken place.

Taken. in its entirety, the most significant occurrence in the last quarter century of the American iron industry was the reorganization of Pittsburg's iron industry upon a new ore supply. This shift from a local ore supply to one

brought a thousand miles from Lake Superior was effected without in any way impairing Pittsburg's rate of growth in iron making or her leadership in the iron industry.

This city had arisen to its position of prominence through purely local conditions of fuel, topography, transportation, and local ore. About 1880, the best of these ores having been used, it was discovered that ores of superior quality could be brought from Lake Superior via the Lower Great Lakes, and thence into Pittsburg at less cost than that at which the poorer local ores could be delivered, and upon this basis Pittsburg has gone steadily onward with its ever-increasing output.

This has come about through the installation of well-nigh marvelous mechanisms for handling raw materials, particularly the ore. This is one of the most stupendous transportation problems and consummate transportation achievements of the present period. In 1884 when England was the iron leader, we began to unload the cargoes of Superior ore with shovels, buckets, windlasses, and wheelbarrows, much as George Washington would have ordered it done if he had required the operation to be performed in connection with his army movements. Within twenty-five years all this has been transformed as completely as

George Washington's stagecoach. The ore is never touched by human hand, and with the exception of a very small percentage lying in the bottom of the ship, it is not even lifted by human muscle from the time it is loosened from its age-long resting place beneath the pine roots of the Lake Superior woods until it goes into a seething furnace on the banks of the Monongahela.

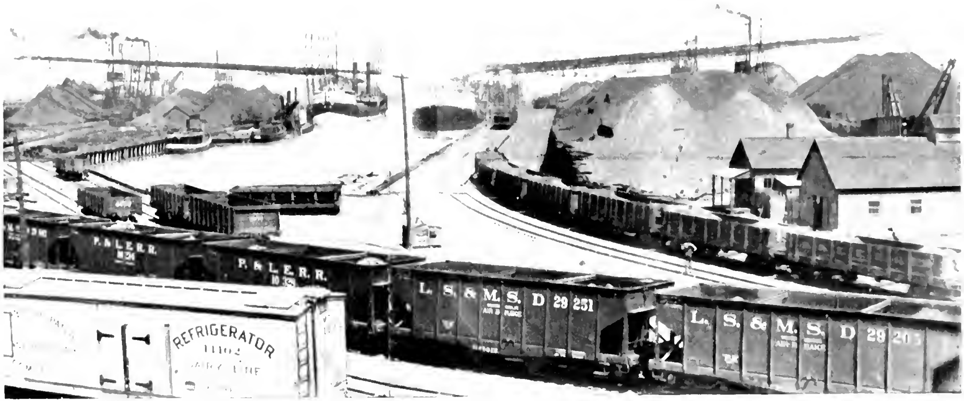
This involves two transshipments and carriage upon two railways and a steamship. Some of the Lake Superior mines are so favorably located that the ore can be taken out by steam shovels in the manner identical with that of digging a railroad cut, now familiar to nearly everyone. For a few cents per ton the ore is thrown upon cars which are drawn away from 10 to 100 miles to the upper lake ore docks situated high upon the bluffs. From this height the ore runs from the bottom of the car into the top of the ore bin on a high wharf, thence through chutes into the hold of a steamer below. This gravity loading serves to fill the steamer in a minimum of time, and almost before she is tied to the dock she is ready to depart for the lower lake port. Here the speed and method of unloading eclipse all records. Special machinery has been evolved whereby steam and electricity operate huge

buckets that grab into the ore in a ship's hold just as a boy's two hands might grab sugar in a barrel. They close upon it and lift it just as easily as the hands could lift sweets. Some of these grab buckets seize as much as ten tons at a time, and there is a row of them, one working at each hold of the ship, which is open from stem to stern. In 1901 a machine that could unload 6,000 tons in 8 to 12 hours for 7 cents a ton was thought to be highly efficient. Shortly after this the 6,000 tons were unloaded by machinery in from 8 to 10 hours for less than 7 cents a ton. In 1903 the record for 5,000 tons by another machine was 3 hours, 36 minutes. This plant with its crew of 17 men would, with the best type of ship, handle 10,000 tons in 6 hours, and during six months of 1903 it handled 2½ million tons of ore, and although the plant cost a quarter of million dollars, it handled ore for less than 4 cents a ton. But the next year this, too, was outdone, and a new plant whose grabbing hands handled 7½ tons each could be operated by two men who, by merely touching levers, controlled 150 horse power and unloaded ore for the astounding cost of 2 cents per ton. This low cost was contributed to by the fact that the machine could reach ninety-eight per cent of the ore in the bottom of the boat rather than requir-

ing hand labor to gather up the last part, as was common with most of its predecessors.

All of these unloading devices run the ore back long distances on high bridge cranes. Anywhere along this journey the touch of a treadle will dump the ore by gravity into cars beneath, provided it is desired to ship it at once to the furnaces. Owing to the fact that the season of lake navigation is open but seven months, and the blast furnaces operate night and day for years, it is necessary to carry down the lakes in seven months the ore supply for the whole year. Accordingly, the lake docks have, when freezing weather comes in the fall, whole mountains of iron ore which will last until the opening of navigation in the ensuing spring. During the winter the same unloading appliances that raised it from the steamer's hold pick it up from storage piles and load it onto cars to be forwarded to furnaces. Most of it stops in the Pittsburg district, which includes the upper Ohio Valley and adjacent sections west of the Alleghenies, but some of it goes as far west as St. Louis, and considerable quantities cross the Alleghenies to be mixed with eastern and imported ore.

When the ore reaches the blast furnace, cars carrying it run upon high trestles, whence it



ORE DOCK ON THE GREAT LAKES WITH ORE HEAPS FOR THE WINTER SUPPLY OF FURNACES.

drops through the car bottom directly into the storage bins of the furnace. These bins, in turn, are opened at the bottom, where the little cars in the tunnel beneath them receive and weigh out the charge required by the furnace alongside. These little cars haul a ton or two, and roll by gravity onto a lift called the skip hoist which carries them up an inclined plane and automatically shifts their cargo, still unlifted by human hand, down the throat of the furnace.

This complete incarnation of the spirit of power gives the Pittsburg furnace the thousand-mile ore of Superior at a cost that Europe finds difficulty in excelling. Upon the English railroad ore freights and iron freights are several times as high as corresponding rates in the United States.

Nor does this American emancipation of muscle stop at the furnace throat. It follows the product clear through to the finishing and loading of the same upon the car consigned to the consumer.

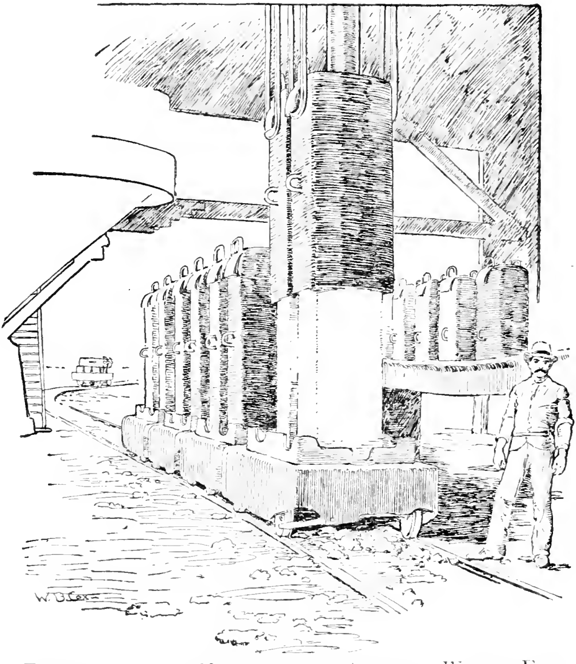
The old-fashioned way of handling pig iron was to run it off into molds in the sand of the casting floor, scatter water over it to cool it a little, break it up with a sledge, and while it was still astonishingly hot, carry it out by hand so

that the floor could be prepared for the next run. This is a process that the Pittsburger knows little about unless, perchance, he reads or has reached the age of reminiscence. If he wants pig iron he makes it in a casting machine which consists of a series of shallow buckets or pails into which the ore runs and rides away on an endless chain which, as it turns over a pulley, dumps the disks of slightly cooled iron into a vat of water or into some convenient pile where the cooling is completed. A similar lift hoists them from the cooling vat and dumps them on a car for shipment. All this mechanical casting has been done for three cents a ton, but this, too, is too slow for Pittsburg. Since Pittsburg iron is destined to become steel, why cool it when it must be heated again? They have ceased the wasteful practice. The iron runs by hundreds of tons from the furnace directly into 25-ton ladles on cars, whole trains of these cars being drawn by locomotives from the furnace to the steel works near by. There the product is dumped into a great mixer which equalizes the product of a dozen furnaces, and from the mixer it flows into the Bessemer converter, or into the open-hearth furnace, where it is promptly turned into steel. As the steel flows away from this fiery purification it is made

into a great ingot weighing upward of three tons.

Steel is not made with hands. In the iron and steel industry of America mechanism rules supreme. Man does little more than touch levers, while the balance is done by steam and electricity, hammering and pulling and lifting with a force unknown to the giants of mythology. Four huge Bessemer converters holding 15 or 20 tons of molten iron do their work by an air blast driven through molten metal by the force of an engine. The air blast and the hydraulic force which swings the converter as easily as a clock does its pendulum are both controlled by two men sitting in a cool breeze on a high platform at the far end of a large shed. The electric cranes swing the 20-ton charges of molten metal and the heavy converters as easily as the school boy swings his dinner pail, and pours the new-made steel into a metal mold which already stands upon a train with a snorting little locomotive ready to take it to the hydraulic machine which draws the mold from the red-hot ingot. Away runs the train to the steel mill, where an electric arm places the 7,000-pound ingot in a seething soaking pit, to keep it hot until it starts down the rolls, which may make it almost anything—a steel rail or beam for a railroad bridge

in India, a girder for a sky scraper for New York or San Francisco, a rib of a ship for Phila-



A Train of Filled Molds at the Stripper, Where Each Mold Is Lifted Off by Hydraulic Force

delphia or Chicago, or a little billet to make a wire fence for the farmer's pig lot, or nails for the carpenter's resounding hammer.

The manless way in which the 7,000-ton steel ingot is turned into a usable piece of steel, after it comes from the soaking pit, never ceases to be a marvel to the knowing inspector of a great steel works. It is always a particular amazement to the European visitor. At first great machines are seen, but the plant appears to be deserted. You ask yourself why this great building is deserted at this time of day. While you ponder thus there arises a rumble and a roaring noise as a great chunk of red-hot metal larger than a man is seen to travel with all the independence of a serpent across a lot of black rollers and dive into the jaws of the great rollers which squeeze it into a flatter shape. The ingot then knowingly stops, turns over and again dives with a crackling noise through the same rollers, which flatten it still more. After this has been repeated a few times the amazed spectator happens to discover sitting on a high platform a man or two who are pulling levers which start the machinery of the six or seven thousand horse-power engines that drive the knowing rollers, which are crushing and rolling the ingot of steel by quick stages into the shapes which men can use.

The process is short by which the ingot is started in at one end of the steel mill and

emerges a half hour later, a fifth or even a third of a mile away, at the other end of the mill, a completed rail.

The economy of this process lies partly in the great size of the operations and partly in the successful use of machinery, but especially in the careful working out of mechanical details assuring that there is no delay. The owner of a small blast furnace has related to me how an employee who celebrated too enthusiastically on one of the national holidays permitted a break in the machinery, due to his semiintoxicated condition. The break cost $800 in repairs, but it threw one of the blowing engines of the blast furnace out of commission for several days, during which time the loss of profit on business that was not done amounted to about $4,000, and the labor cost of the monthly output was heavily increased.

A Pittsburg blast furnace having two engines for the air blast has a third $50,000 engine standing idle in reserve. The manager remarked that without it the breaking of an engine would reduce the capacity of the furnace 250 tons a day and the reserve engine would therefore pay for itself in between two and three weeks.

The experience of the Carnegie Steel Company in the substitution of machinery for man has

been that they can profitably spend as much as $1,000 for machinery to replace the work of one man. It is by such provisions as these that the American plants have attained their exceptionally large capacity, but the final factor of success is the organization and perfection of small improvements which permits the almost continuous operation of the plants which do not break down.

The Bessemer converter which changes molten iron into steel in less than a quarter of an hour is inverted to dump its charge, and, presto! two men come up behind, peer into the air tubes, which are the vital parts, and, by a tap and a bang and the setting of a wedge they can repair and replace, and by the time the last molten froth is gone the converter is ready for the next charge. By this means with 12-minute blows the converters make from 50 to 70 heats of metal in an 11-hour turn. This well-nigh continuous stream of hot metal if cast in the old-fashioned English mold on the floor would create an impossible situation through the unbearable heat of the cooling molds and the occasional explosion within the molds. Some method must provide for the continuous passage of this steel, which is accomplished through having large metal molds mounted on cars, and within thirty seconds after

the last stream of fluid metal has run from the ladle, a train carries the red-hot load out into the open where the molds can cool without making sweat for the brow of laboring man.

This smooth and uninterrupted handling of the molten metal is the critical point in the whole steel-making process, which in the modern plants starts with the ore and completes the process in a single plant, which simply *cannot* be permitted to break down. The successes of this substitution of hand labor by machinery, continuously operating, is forcibly recognized by a careful British observer who, after visiting scores of our plants, declared: "Perhaps the greatest difference between English and American conditions in steel-works practice is the very conspicuous absence of labourers in the American mills. The large and growing employment of every kind of both propelling and directing machinery—electric trolleys, rising and falling tables, live-rollers, side-racks, shears, machine-stamps, endless-chain tables for charging on to cars, overhead travelling cranes—is responsible for this state of things. It is no exaggeration to say that in a mill rolling three thousand tons of rails a day, not a dozen men are to be seen on the mill floor. To stand on the floor of such a mill and to witness the conversion, in the space of half an hour, of a

red-hot steel ingot weighing several tons into finished stamped steel rails 90 feet long, and all this practically by the agency of unseen hands, is to gain new ideas of the possibilities of mechanism—of the subservience of matter to mind. This is the romance of steel evolved from the mind of the twentieth-century American engineer."

Specialization is another means by which American iron and steel manufacture has been enabled to advance so far and so rapidly. A great plant devoted to making one or two single products has little more complication than a single machine, and it possesses great economy of superintendence and great economy in the equipment of machinery of the most advanced type for its operation. And then, this machinery is constantly employed to the reduction of capital costs. The plant that is equipped to make a variety of products may have much idle capital in the form of machinery lying unused for a part of the time. In Pittsburg there is a great axle plant, and many plants are devoted to the making of car wheels. At Coatesville, Pa., Worth Brothers are makers of steel plates, and it is not surprising that their Exposition exhibit at St. Louis should have contained the largest plate ever rolled. This specialization is by no

means limited to the few examples cited, but it is to be found in greater or less degree in almost every branch of iron and steel industry. It has not had a similar development in Europe because their cheaper labor has not driven them to such great dependence upon machines, and while man may do a variety of things, a single machine cannot so easily adapt itself.

Yet another factor and one second to none in importance is the practice of integration, through which the various stages in the process of making finished steel are controlled by one company. This gives great opportunity to reduce the cost of superintendence, control the quality of raw materials in the various stages of the industry, and, above all, to combine profits. The effect of this factor will be considered in another chapter.

CHAPTER IX

THE CARNEGIE STEEL COMPANY

An account of the story of steel, either in the United States or in the world, would be incomplete without reference to the Carnegie Steel Company, of Pittsburg, which has occupied so strategic and dominating a position in the steel industry, and which has been such a maker of steel and of history of steel. Without a clear knowledge of the part that this company has taken in steel and steel strategy, the mainsprings of twentieth-century history remain invisible and mysterious. This company has been foremost in the developments which have been described in a previous chapter as the characteristic factors which have made America a predominant factor in twentieth-century steel manufacturing.

During the period when England led the world, the unit of steel making was the individual mill or individual furnace situated in some district with many more like it and equally independent of it. The enterprise was indi-

vidualistic, and with such conditions the superior natural conditions of England counted, for it was easy for the individual or single small-company plant to achieve results. America has forged ahead under the mighty constructions and operations that have been brought about by great companies. In this movement the Carnegie Steel Company has always been a leader.

No industry is naturally so uncertain and consequently so competitive as the steel industry. The demand for the product is fitful and uncertain in the extreme because most of it goes into new constructions and new enterprises, and these are notorious for the spurts and depressions of demand which affect them. While the consumption demand for iron and steel rises and falls, the purchasing demand is often more uncertain, because the users wish to take advantage of favorable markets to provide for their future needs. Anybody will buy on a rising market because of the belief that prices will keep on rising, and that it is desirable to buy before the future rise in price occurs. This rush to buy on a rising market sends prices soaring. Once they have started down, however, there is the same widespread belief that they will go lower. Therefore the belief that it will pay to hold off. It is astonishing how the experienced buyers at such a time

can wait and wait and bide their opportunity to fill their requirements at the lowest figures. Their waiting makes the product pile up at the mills and furnaces, and the price goes down and down until after many weeks, usually several months, there is another revival. Such cycles, oft repeated, seem to make the normal history of the iron and steel trade under competitive selling. The loss due to the slump period often more than overbalances the gains made in the sharp rise. This fact has long been known to the manufacturer, but a hundred independent makers could not agree on prices. The temptation of a fierce demand was always too much for some seller. He could not resist the temptation to ask $5 or $10 advance (clear profit) when he knew that to ask was to receive. Before the coming of the Trust the purchaser was always made to pay all that he would, whether it were $8 or $40 a ton. On the other hand, when demand slackened, no agreement could be made sufficiently binding to prevent the producer from cutting prices to secure orders. He had to do it or fail.

The uncontrolled iron and steel market can make these wild rises that are unknown to so many commodities, because it is difficult to suddenly increase the amount of manufacture in response to sudden demand, and more especially

because the products are the raw materials of other industries. A thousand industries must have iron or steel or they cannot go on. A wave of prosperity sends them all clamoring, begging for steel. These aggressive, insistent importunities rapidly advance prices. If necessity presses him the machinery manufacturer can increase the price of his iron purchases by a much greater percentage than it is necessary for him to charge on the finished product. The standard price of a certain machine is $100. The supply is exhausted. A purchaser who sees profit in using the machine offers $125 for quick delivery. The original price of $100 included profits of the manufacturer, interest on his capital, taxes, insurance, fuel, repair of buildings, cost and repair of machinery, labor, and, finally, $10 worth of iron and steel. The sudden offer of a higher price for the finished machine affects these manufacturing costs but little. If necessary, in order to obtain it, the machine manufacturer can easily offer $20 or $25 for the material he formerly secured for $10, or, in other words, can raise the price of iron and steel in this transaction one hundred or one hundred and fifty per cent. These higher prices are paid by a man who made a profit thereby, perhaps a large increase over his usual profit.

The competitive prices of iron and steel are the footballs of industry, bounding up and down at the caprice of forces much more steady than themselves. The iron and steel industry has well merited the name of the industrial thermometer. When hopes run high and projects expand, men buy iron and steel in every form, from tacks and staples to trainloads of rails and beams. With these materials they start industry, and as the industrial sky darkens, the purchases of iron and steel cease as suddenly as they began, and the price must tumble if the output is sold.

These conditions were the normal state of affairs through which all steel makers lived down to the period when they went into the great depression between 1893 and 1898. During this time the demand was at its lowest, and iron prices reached their very bottom. The numerous independent manufacturers now thought that if they could just get together and agree upon prices they could greatly improve their miserable condition. Many attempts to achieve this were made in the form of pools which provided that each of the makers of a certain material for a certain market should make a stipulated proportion of the product to be sold at an agreed price. If a factory made more than its share, the

owner made a cash payment to the pool and the money went to some manufacturer who had made less than his share. The weak part of these pools was their absolute lack of power of coercion, and a thing that was still more detrimental was that no member had faith in the others, and this lack of faith was often well founded. One of the pools went to pieces because it provided for the sale of certain raw products and omitted to cover certain slightly more manufactured grades. Some members of the pool promptly converted much more than their share of the product into finished goods, thus violating the spirit but not the letter of the pool, which was thereby destroyed. As in that period of common railway rebates, the same men were equally willing to give rebates in the selling of their iron goods. Consequently, the pools were always short-lived. Furthermore, the pool was ruled by majority rule, and the majority of the members of any industry are not likely to attain the wisest opinions concerning it. In this period of pools their weaknesses were so thoroughly learned that the heavy buyers regularly held off from purchases, knowing that the pool would soon break and they could come much more nearly to having their own way with the competing manufacturers. When a pool did go to pieces, the scramble for orders often put the

price down to a lower point than that which had brought about the formation of the pool.

The failures in the attempts at price control by many independent companies did not in any way lessen the desire of everyone in the industry for some form of price control. As it could not be had by coöperation of independents, it finally came about through the consolidation of many under one control. The period of 1898 and 1899 was one very active in the formation of trusts of all kinds in America, and in the world of iron and steel there was great activity in trust formation. It took the form of the consolidation of what had been rival companies in the manufacture of some particular line of iron and steel goods. The names were easily descriptive, as, the American Steel and Wire Company, the American Bridge, the National Tube, the American Tin Plate, the American Steel Hoop, the American Sheet Steel, and other companies. One of these trusts was almost formed without even a promoter. A convention of tin-plate manufacturers appointed a committee to wait upon Judge Moore, who had attained some fame through the promotion of the National Biscuit Company, and ask him to form a consolidation among them. The president of the American Tin Plate Company stated before the Industrial

Commission that his company was formed "for the purpose of getting together and doing away with foolishness in making prices" . . . the foolishness, in his mind, of course, being price-cutting competition.

While these companies were formed as the result of the stimulus of depression and lean years, they could only be brought about by the financial conditions of the period of returning prosperity. Naturally, a prosperous mill was not to be had cheaply. Each manufacturer whose plant was bought out sold at a figure which capitalized his present profitable earnings, and possibly his hoped-for future earnings. This was but human nature, and the trust formers therefore had to face the difficulty of starting with heavily over-capitalized companies. Six of the largest of these companies which afterwards entered into the United States Steel Corporation, having a capital of nearly half a billion dollars, had at least fifty-three per cent of this capitalization in the form of common stock, which admittedly represented no present value, but was merely value in prospect.

These trusts had the disadvantage of being formed by Wall Street makers of stocks and bonds rather than by the makers of iron and steel. They were the financial operations of

financiers who made the stocks to sell, as by that means they got their profit. To make these securities sell quickly, it was therefore very urgent that the companies should pay good dividends, and raise the value of their securities. This was done to the violation of the rule that such companies should place a large portion of their profits to reserve. This policy is necessary in railway management, as witnessed by the practice of the best American and European railways, and it is much more important for an industrial concern, particularly a steel works, because of the short life of the plant and the great uncertainty of the business.

The consequence of this financiers' dividend policy was that the steel trusts of 1898 had by 1901 accumulated but small reserves to tide them through a rainy day, which was then upon them. All had gone peacefully until the fall of 1900, because the prosperity of trade kept them all busy. In the spring of 1900 there was a reaction in the steel market which continued until November of that year, making it necessary for the steel companies to adjust themselves to smaller profits. This meant a cutting down of expenses somewhere or the increase of profits through the extension of the territory of sales into regions which had before been in the undisturbed pos-

session of rivals. Here again was the specter of competition which had thus far not faced the great trusts. The first move to cut down costs threatened to loose the war dogs in the steel world.

The chief companies which later became members of the United States Steel Corporation were at this time in two groups. Each group may be classified according to the product. First, the manufacturers of unfinished steel such as ingots, billets, bars, plates, and slabs. These were turned out by the Carnegie Steel Company of Pittsburg, the Federal Steel Company, and the National Steel Company. These companies sold their unfinished products to the second or finishing group of companies: the American Tin Plate, the National Tube, the American Steel and Wire, the American Steel Hoop, and the American Sheet Steel Company, whose names indicate them to be manufacturers of finished goods. These two groups of companies may be said to have dominated the region between the Ohio river and the Great Lakes, and the Alleghenies and Chicago. The Carnegie Company was centralized at Pittsburg, as was the National Steel Company, while the Federal Steel Company had its most important works in the vicinity of Chicago. The finishing companies had widely scattered mills

nearer to their markets and were large purchasers from the raw material producing companies.

The first thought that came to the minds of the finishing group when hard times compelled them to cut down costs was to cheapen their raw material costs by becoming manufacturers of their own pig iron. In this independence of all outside supply, the trusts had had before them the successful example of the Carnegie Steel Company, which had as early as 1882 adopted the policy of combining under one control the production of the raw materials needed in its operations. In that year the company purchased the controlling interest in the H. C. Frick Coke Company, the largest owner of the coal lands and the largest producer of coke in the Connellsville region. From this source the company secured coke so cheaply that the minority holders of the Frick Company complained in court that they were being cheated out of their just profits. The Carnegie Company possessed itself of ore supplies and of transportation facilities and in 1897 had control of large ore regions in the Lake Superior district and, in addition, made a fifty-year contract for a yearly supply of a million and a half tons of ore delivered at the Lower Lakes. The company also secured control of the Pittsburg Steamboat and Steamship Company,

owning in 1900 eleven steamships, two tug boats, and six steamers under construction. It secured control of the Pittsburg, Bessemer and Lake Erie Railroad, extending from the lake port of Conneaut, where there were large ore docks, to the Carnegie mills at Duquesne, near Pittsburg. This railroad was reconstructed, equipped with hundred-pound steel rails, had the first steel cars used in this country, and had the heaviest locomotives. By the aid of these improvements, ore was carried at cost, at the almost unknown figure of one mill per ton mile. The Carnegie Steel Company was now independent of other companies in the supply of its fuel, its ore, and the transportation of the same, and was free from the fluctuations of cost in these supplies. The profits of these subsidiary operations were cost factors for their rivals, and profit factors for the Carnegie Company. These equipments, in addition to the splendid mills and furnaces, placed the Carnegie Company in the foremost position among the iron and steel makers of the United States and of the world.

When hard times pinched the trusts in 1900, they set out to strengthen their position by emulating the shining example of the Carnegie Company. The American Steel and Wire Company possessed itself of extensive coal lands and of

lake steamers for the transportation of its ore. Furthermore, it announced its intention of building furnaces at Chicago and started the construction of others near Pittsburg. Other finishing companies announced the same intention, and backed it up by the purchase of ore lands, fuel lands, and transportation facilities.

Now the Carnegie Steel Company and the Federal Steel Company had been for years employed in making the raw materials for these finishing companies which thus suddenly announced their purpose to supply themselves with these essentials. Naturally, the raw materials group could not view this operation with unconcern. It meant the loss of their market and the necessity of their seeking new markets elsewhere in the United States or in foreign countries. Neither the Federal Steel Company nor the Carnegie Steel Company had any intention of thus weakly considering themselves wiped out of existence or compelled to seek an outlet in foreign lands. The Federal hurriedly increased its holdings of ore and coal, of upper-lake railways, and of lake steamers, and secured 316 miles of railway connecting its plants with Chicago. It announced that since the finishing companies were going to make their own raw material, it would have to make up its own products into finished

commodities, thereby competing with the finishing companies. Mr. Carnegie faced the same situation in Pittsburg with the same announcement. In January, 1901, he said that he was going to build a finishing mill at Conneaut, Ohio, at the end of his ore railway, where the returning ore cars could supply it with fuel at a minimum cost. It was to eclipse anything the world had seen. It was to be upon the shore of the lake, was to be a mile long, and was to start with the ore at one end and load cars with the finished products at the other end. In equipment the mill would be without a rival in the world, and at the same time the company was preparing to build a railway to give better freight rates and a more satisfactory outlet from Pittsburg to the tide water and the eastern markets. Now arose agitation similar to that witnessed when a stick is poked into a nest of ants.

The consternation among the steel trusts was extreme. They were threatened with competition by a company which could remove from them all hope of dividends so long as its competition lasted, and which they could not possibly hope to seriously injure. The Carnegie Company was not of their kind. Its plants were the best equipped in the country, its control of raw materials the most perfect. The plants were

situated in and near Pittsburg, where control was easy, and where conditions of manufacture were most economical. The American Steel and Wire Company, being an aggregation of many small, independent compañies, had plants in ten States, the Federal Steel Campany had plants in eight States, and the American Tin Plate Company had plants in five States, many of these scattered plants being located where some small company had settled because of the donation of a free building site, a cash bonus, a special freight rate, or an exemption from taxation for a given period of years. Industrial competition among such rivals could have but one result, and the steel-finishing companies' promoters knew what that would be. So did Mr. Carnegie.

The strongest factor in the Carnegie Company's position was its financial status. The rival trusts had been made by expert manipulators of stocks and bonds. Mr. Carnegie remarked that he knew little about stocks and bonds; he was interested in making steel. The trusts were overcapitalized aggregations. The Carnegie Company was tremendously undercapitalized, in that it had been built up by surplus earnings. In 1890 it had an annual capacity of 295,000 tons of steel and in eight years, most of it a period of depression, it had out of

profits alone made new constructons and betterments, so that its output had increased nearly ten-fold. During the years 1898 and 1899 the profits of the company exceeded $70,000,000, and of these $20,000,000 had gone into new constructions and betterments. "Every new process and every new machine which would in any way increase the efficiency, reduce the cost, and improve the product of the Carnegie Company has been adopted until this great concern has brought the physical condition of its mills to a point which is unsurpassed."[1]

Such was the invulnerable equipment, resource, and financial situation of the Carnegie Company when at the beginning of 1901 it threatened to compete with the new-made trusts of the underwriters. Not only did these men foresee the immediate ruin of their new creations, but they saw, moreover, that they could not realize their desired prifits, which they could only get by the successful selling of the yet unsold stocks which they had taken as their profit in the trust organizations which they had effected. If they competed with the Carnegie Steel Company, they lost their money; if they backed down from their announced plans, they lost prestige through their

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[1] *United States Investor,* February 9, 1901.

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STEEL PLANTS AT (1) DUQUESNE, PA., (2) MUNHALL, PA., (3) BESSEMER, PA.

These three huge steel plants were the basis of Mr. Carnegie's fortune.

abject surrender. The only possible alternative for them was therefore to buy out Carnegie and his steel company and form the United States Steel Corporation, which combined all the great trusts and permitted all of the control of raw materials and transportation which they had planned.

CHAPTER X

THE STEEL TRUST AND ITS RIVALS

As related in the last chapter, the formation of the Steel Trust was the final attempt of the producers to control the low prices of which they had become so sick in the era of unrestrained competition by the many small independents. Pools had failed, and the earlier trusts, aiming at monopolizing each line of the iron trade, had in the first temporary depression come face to face with the immediate prospect of ruinous competition among themselves. Then came the supreme and final effort at definitely and finally controlling the prices through the creation of the most stupendous corporation that man has yet dared to launch—the United States Steel Corporation. The final consternation that drove to this heroic remedy was Mr. Carnegie's announcement of January 12, 1901, that his company was going into the steel-finishing business, and any combination that was to control prices had to control Carnegie, and, as he could not by any means be beaten out, he had

to be bought out. This was finally accomplished and the steel corporation began its first year within three and a half months after Carnegie's threat was made, but as the negotiations advanced, Mr. Carnegie's appreciation of the value of his own property, and particularly of the strength of his own situation, caused his price to jump and leap by scores of millions, until finally the Wall Street financiers, under the leadership of Mr. Morgan, had to ransom their watery steel trusts by mortgaging the future and giving Mr. Carnegie such a shower of gold as had never before descended upon mortal man, and would have made the classic Crœsus open his eyes wider than would the sight of one of Mr. Carnegie's blast furnaces on a sultry night.

The new-formed trust, made to get rid of Mr. Carnegie and control prices, has been a success, although it was not a monopoly. It controlled, roughly, about two thirds of the steel output of the country. Of the plants making the remaining one third, some were in such small units as not to be worth seeking, and some could not be secured by the Trust promoters.

In 1901 there were many strong companies equipped for absolute independence. While most of them went into the Trust, some of them

did not, and still retain their entire independence. At Johnstown, Pa., the Cambria Steel Company maintains a smaller edition of the United States Steel Corporation. Its special products are steel rails and structural material which are made from ores taken from its own extensive holdings on Lake Superior and smelted with coke of its own making. The great firm of Jones & Laughlin, at Pittsburg, makers of structural steel from materials of their own mining, are as independent as the Trust, into which they could not be induced to go. The Lackawanna Steel Company has a magnificent, new, and thoroughly modern plant at Buffalo on the shore of Lake Erie, where the ore steamer can discharge its cargo at the foot of the blast furnace, from which the heated metal starts on its journey through the plant and never cools until it emerges a steel rail—the specialty of the company, made from ore of its own mining, smelted with fuel of its own digging. The Pennsylvania Steel Company, with works on tide water at Baltimore, has ore lands conveniently situated in Cuba, and makes a specialty of bridge work and steel buildings. The Bethlehem Steel Company has ore lands in Cuba, and the leading steel maker of the South, the Tennessee Coal and Iron Company, like many

others, digs its own raw materials. The financial flurry of November, 1907, enabled the United States Steel Corporation to buy the latter—a most suggestive episode.

But these independents while complete, are complete in miniature, so far as the product is concerned. The United States Steel Corporation — the Trust — is the giant figure whose shadow spreads across the whole world of steel.

This trust stands in wonderfully varied regard among different classes of our citizens. In respect to size, it is certainly the dean of the corps of ogres to those to whom the trusts are ogres. And this class is large. The people of this country fear the trusts to-day as our Revolutionary ancestors feared kings and despots. Their dread arises from the conviction that the trust has, or will get, supreme power in the control of one industry, and then, like the typical despot, use that unrestrained power to take unfair and injurious advantage of defenseless persons. There are two classes of persons who might be injured. One is the purchasing public, who might be forced to pay unreasonable prices. The other class is the rival producers. Here we find friends for the Steel Trust in the last place where one would naturally seek them.

A trust whose existence and actions create

joy among most of its rivals is an unexpected spectacle in American industry, yet such is the present esteem of the Steel Trust among its smaller brethren of this hot and smoky industry. This friendly attitude has resulted from a profitable and satisfactory price control, resulting in benefits that all have shared. The United States Steel Corporation could only make profits by maintaining a profitable price for its products, and as this price necessarily reaches over the whole field, the independents have in nowise suffered. They have had all the benefits of trust prices without any of the hardships resulting from trust forming. They fatten like the wolf pack which follows the camp of the successful hunter of big game.

During the last few weeks of 1906 the writer interviewed many independents to ascertain how they regarded their towering rival. It was found that there were two points of view held by the two groups of industries that constitute the world of steel. The first of these groups is composed of the men who make pig iron. Their product is the raw material for the second or finishing group, who take pig iron and convert it into steel, which they manufacture and sell as a great variety of finished articles. Others, with a still narrower field of finishing

operation, buy billets, or blooms, or rods of steel for further manufacture. The iron makers view the Trust rather more complacently than the finishers. The iron makers are plainly jubilant. When I asked one of them how the United States Steel Corporation was affecting his business, he turned to me in a significant way and said: "Say, Mr. Smith, have you found any producer who had any complaint to make about the Trust?" I told him that I had not. I had found them satisfied because they had been free to make and sell iron; they admitted that the steel corporation had helped them by the price regulation which it had inaugurated to increase its own profits. One surprising part of this price control is that the greatest manufacturer has at times refused to accept very high prices for its products. It has prevented sharp rises to the heights of fabulous profit that there might be no falls to the depths of stagnation and bankruptcy.

These are rather strong claims, and at first glance a chart of prices seemed to withhold verification, but a closer examination of such a chart shows that in the main the statements of the independents have truth in them. The very high prices of 1899 and 1900 were about to be followed by industrial war; that is to say, vigor-

ous price cutting among the great companies that had suddenly found themselves in a position of keen rivalry in iron and steel making. The anticipated fall in prices was prevented by the consolidation of the belligerent rivals into the Trust. The new company began business in April, 1901, and a comparison of prices since that date shows distinct differences from those of a similar preceding period. During twelve months in 1898 and 1899 the price of steel rails rose more than one hundred per cent. For the past four years it has not changed, although a bonus of several dollars a ton has at times been paid for prompt delivery. In the boom of 1899 nails had jumped from $29 to $71 a ton, an increase of one hundred and forty-five per cent. Since 1901 fluctuations have not exceeded thirty-five per cent. The price of pig iron has fluctuated more than the others, but in the price of this commodity several factors should be noted. It is in the production of pig iron that the Trust plays its smallest rôle, and its power to influence the market is lessened because it is not a pig-iron seller and is a constant purchaser. The most significant thing about the pig-iron price is the general agreement among independent manufacturers and iron-trade journals that in the bounding prosperity of Novem-

ber, 1906, the pig-iron price would probably have been $30 per ton rather than the $20 to $22 price that the Trust was able to maintain.

This price-steadying is of incalculable benefit to the independent manufacturer, even when it limits the heights to which a price spurt will go. The apparent contradiction of benefit from temporary lessening of profits is explained by the fact that rapidly rising prices start a feverish intoxicated condition of the market, which is very pleasant while it lasts, but, like most intoxication, is followed by a yet more unpleasant reaction. Therefore, the Trust tries to keep sober and keep its little brothers sober also, and all are profiting by the new temperance.

Through its mere size the United States Steel Corporation can control many prices by simply maintaining quotations to which buyers must conform. Such control, however, is much easier in the preventing of high prices than in keeping prices from falling. It is stated on good authority that most vigorous means have been taken to control the pig-iron market. Pig iron is the raw material of the steel mills. The Trust is a great manufacturer of pig and also a large buyer, since its own furnaces are still inadequate to supply its converters. There have been

times when a feverish pig-iron market threatened to send prices up to dangerous heights. Everybody wanted pig iron. So did the Trust. Rather than disturb settled conditions, however, at such periods, the Trust has withdrawn from the market for a time and has incurred a loss in sales of finished product in order to maintain settled prices for iron. The withdrawal of the largest buyer has an instant effect on the pig-iron market, and prices do not advance. Again, at times when iron prices threaten to tumble, the Trust has gone on the market and bought heavily, even though it required the closing here and there for the time being of some of its own furnaces. This control of prices is exerted with profit to the controller. If the independent maker shares in the gains, so much the better for him. His participation was not intended. The Steel Trust is not a philanthropic institution. It is after dividends which it sorely needs. Incidentally, the independents have prospered exceedingly, and at times, as in the case just mentioned, the Trust can afford to allow some independents to take a slight temporary advantage. This advantage, however, is slight; one per cent of output more or less changes a dull market into a brisk one. One extra purchaser, when the iron is all en-

gaged, keeps it brisk; one seller, when the buyers are all satisfied, makes a dull market.

It is not every rival of the Steel Trust who is so happy about its existence.

The second class of independents, the finishers, are by no means so well pleased with the Trust as are the iron makers. The finisher is more directly the Trust's competitor. Both are selling finished products, both are buying pig iron as raw material. Some of the smaller finishers buy various kinds of steel for further manufacture and sell it in competition with others of their kind, with the Trust and with several of the great independent concerns, which are like the United States Steel Corporation, in that they perform every process from taking the ore out of the earth to selling or even putting in place the finished steel.

Those makers who are like the Trust in their independence are not concerned. It is the one-process finishers who are dependent on the open market for their raw material who do not share the iron makers' joy. Some phases of the Trust's policy look toward the ultimate injury of and the possible disappearance of the finisher who cannot make his own raw materials. There appears to be a general policy of holding down the price of finished goods and gradually rais-

ing the price of raw materials. Here are two millstones that have already done some grinding upon some branches of the steel industry. The Steel Trust rarely sells raw materials, and then it is usually for strategic purposes, but it is securing and holding them in vast quantity. At the present time, while pig iron is bought by many steel mills as the raw material for their manufacture of steel, no firm can make steel if it depends upon the Trust for iron, although when first formed the Trust regularly sold some iron. The manufacturers of steel goods, including wire, fences, nails, and many kinds of heavy hardware, buy as their raw materials steel billets, which can only be made in mills of great cost. The Trust holds the price of billets so high and the finished goods so low that no man can buy billets from the Trust and manufacture at a profit, and for many months at a time the price of billets has been held so high that some stages of manufacture beyond billets were open only to the firms in a position to make their own billets. This is a great blow to small manufacturing concerns and enormously increases the capital necessary for starting or prosecuting such an industry. At the same time the Trust is now building in Indiana a wonderful new plant, which will be devoted to the manufacture of

small steel goods, practically heavy hardware. It can, by being its own supply, beat all rivals in the securing of cheap raw materials for this branch of the steel industry.

At the formation of the Trust a shrewd and powerful blow was struck at rivals then unborn. There was so nearly a monopoly of tin-plate mills that the stove and hardware manufacturers, who use as their raw material a great variety of sheet metal, were compelled to deal with the Trust. Many of these manufacturers had trade-mark brands for which they had spent years in developing a market through diligence and advertising. The Trust managers knew that some of the hardware men would turn to the first independent mill that sprung up, and having the hardware producers temporarily at their mercy, they compelled the signing of contracts giving the Trust mills the exclusive privilege of making the trade-mark brands for fifteen years. The hardware makers now have an agreement by which independent rolling mills make twenty-five per cent of the sheet metal, but this does not include any of the trade-mark brands covered by the long contracts.

Upon the whole, the steel maker who does not control the entire process, that is to say, the single-process man, is getting into a disadvan-

tageous position. He may be pinched off by a rival who makes money by duplicating his work at the same cost, and losing money on that particular stage of the work. The continuous-process makers, like the Trust, may lose on one stage of the work and make up the loss on the others. There are many steps between the ore and the finished steel goods, the product of one process becoming the raw material of the next for an indefinite number of stages. The most prominent of these stages are ore, pig iron, steel billets, steel rods, and a multitude of finished products using rods. At the beginning of 1907 the price of billets was so high and rods so low that no rod maker could sell rods in the open market if he bought his billets in the open market. If a firm depended entirely upon such work it would have to close its mills instantly, and for the same reason that it would close, many firms have been compelled to change the relative importance of their lines of business. The one-process man is uneasy, for he is threatened by a movement which is advantageous to the Trust and to the third class of independents, the great firms which are like it in the completeness of their process.

Despite its efforts at control, the Trust is not as near monopoly as it was the day it began.

The four full years of its operation, 1902–1905 inclusive, did not indicate any increased share of production. The bulletin of the American Iron and Steel Association shows that during these four years there was an almost universal decline in the percentages of iron and steel products made by the Trust, the only exception to this rule being in coke and wire nails, which increased slightly. It should be distinctly noted that these decreases in percentages of production, ranging from 0.1 per cent on miscellaneous finished forms to 11.8 per cent on Bessemer rails, are not decreases of actual output. There have been large increases in output all along the line, but the independents have increased at a more rapid rate than the Steel Corporation.

In what, after all, lies the power of absolute control in the steel industry? The experience of four years shows that it does not lie in the most stupendous of corporations, possessing the best and largest plants, the most perfect equipment, the best and most abundant raw materials, the strongest financial backing, and having, at the beginning of its operations, nearly two thirds of the American iron and steel products as its output. This giant may embarrass the one-process finisher, but there are other independents which duplicate all of its work. How does

their position compare with that of the Trust? Can the Trust control them?

The control of the steel industry lies in the control of the raw materials, and while the supplies of the independent companies hold out, the Trust may help its rivals, but cannot hurt them. They are as safe as the crew of a staunch ship while the provisions remain abundant.

It then becomes a question of comparison of accounts at the economic bank—the bank of raw material. Iron ore is the fundamental raw material of the steel industry, since it is the most limited in amount. Concerning iron ore, the Steel Trust has pursued from the beginning a pronounced and vigorous policy, which has already affected nearly every independent steel producer in the country. Control of the steel trade lies in the control of the ore. The opinion has been frequently expressed that in a half century the rich Lake Superior ores will be about exhausted. The Trust is organized, and its plants located almost exclusively on the basis of a Lake Superior ore supply. The company has issued fifty-year bonds, and it has gone forward to secure these bonds by laying in, in a short time, a store of ore to last it approximately a half century. There is no announcement that the end has yet come. By thus taking over ore

property after ore property the Trust has unquestionably raised the price of ore. Some of the independents are alarmed about the distant future, although their present dividends are almost too good to be true. Others of the independents incline to the more comfortable view that monopoly can never be attained and maintained.

Whatever the future may hold in this matter it is certain that the Steel Trust's recent great ore lease from the Great Northern Railway started a great scramble for ores, and set a new and steadily rising price level with which we must abide for decades to come. Never before was there so much activity in ore-land deals. Within a fortnight after the Great Northern lease by the Trust two Southern companies made large purchases in that section, one of them securing a fifty-years' supply of coal and iron ore.

There are two ways of purchasing the ore: One, absolute purchase of the property, land and all. The other, a so-called lease, permitting the exhaustion of the ore at an agreed-upon price and usually at an agreed minimum rate or within an agreed time. The Steel Trust uses both of these methods, and when a purchase is made it is the common practice to draw the

pumps and abandon work in favor of some of the leased properties with a time limit.

The Steel Corporation was credited at its inauguration with having possession of about 700,000,000 tons of ore. Mr. James J. Hill saw that somebody was going to want more ore shortly, and began to buy ore lands furiously in the pine woods beyond Lake Superior. The steel corporation put explorers in this field and in other fields—in just how many fields no outsider can say. Rumors come of ore purchases in Mexico and in South America, but attention has been chiefly concentrated in the Lake Superior region, where three great purchases, with hundreds of millions of tons, had been made before it appeared necessary to deal with the far-seeing Mr. Hill.

After long negotiations, in October, 1906, it was formally announced that the Hill properties were leased by the Steel Corporation. The amount of ore contained can never be accurately known until it is mined. Published reports vary because of different amounts of knowledge and from different desires with regard to imparting the truth. A recent writer in the *Iron Age* stated [1] that the total holdings by the corporation of Lake Superior ores now in sight

[1] October 1, 1906, p. 955.

were probably over 2,000,000,000 tons and those of independents 500,000,000. One thing is certain, the Trust is stocked for half a century to come, but the most striking thing about it is revealed by the examination of the conditions that Mr. Hill exacted from the purchaser. The common method of leases is a price per ton, and the ore to be taken in a certain time. Of late it has been common to exact also a cash bonus at the start, but Mr. Hill eclipsed all by compelling Mr. Morgan's corporation to pay eighty-five cents per ton and four per cent interest from date. This amounts to an annual increase of 3.4 cents per ton. It is not expected that mining operations calling for a minimum of 8,250,000 tons per year will be fully under way for a decade, and during this time the price will already have raised as follows: 1907, 85 cents; 1912, 102.1 cents; 1917, 119.0 cents.

In addition to this rising price of the ore in place, Mr. Hill gets and will continue to get eighty cents a ton for hauling it to the ore dock on the shore of the lake; fifty cents of this rate is commonly considered to be profit. Mr. Hill is safe indeed. The corporation that bought out Mr. Carnegie for such fabulous sums is also assured of an ore supply for a long period at increasing cost. Is that security?

If the process of iron and steel making should not change, it is difficult to see trouble ahead for the Steel Trust. The figures given above show that it may control four fifths of the ore in the best and richest field in the world. There are many independent companies with ore reserves, but well-informed independents agree that the United States Steel Corporation is "preëminently the best supplied." The same men who estimate that it can run for fifty years place the time limit on the leading independents at from twenty to thirty years, although some of them can run longer. Here, then, lies a possible future supremacy in which the Trust will stand virtually alone, as its rivals die one after another beside their exhausted ore pits.

Such a conclusion rests, however, on the assumption that the iron industry continues to be dependent upon its present technical process, which can use only high-grade ores. Such an assumption scarcely does justice to the progress of the age. Iron making will change in the future as it has in the past. Thousands of keen minds, both in Europe and America, are bent upon bettering iron-making processes, and anyone who knows the inventive genius that lies in these thousands of brains knows that there must be progress and improvement. In the past no

industry has been more unstable than iron and steel. It has been pushed about the various corners of the industrial world in a truly amazing fashion. Iron is made from half a dozen kinds of ore and three kinds of fuel. A discovery or invention in any one of these may undo and make over the industry again as it has in the past, and the Trust may thereby be loosened from its strong hold. For example, about the middle of the nineteenth century the splendid smelting qualities of anthracite coal had made the Schuylkill Valley of eastern Pennsylvania preëminent in the iron industry through its monopoly of anthracite coal. But an iron or steel trust organized on the anthracite coal basis would have perished unless it could have entirely changed its basis.

The United States is not alone in having a price-controlling steel trust. In the German steel industry, also, the same end is attained, but owing to the different conditions of the two countries it is brought about in Germany with far less turmoil and trouble than has been the case in America.

They have succeeded in that country with a modified form of the first device which was tried in this country and which met with such a signal failure, namely, the pool. An occa-

sional meeting of the German steel manufacturers enables them to make the necessary arrangements to maintain prices, control output, and continue industrial peace among themselves.

It would be difficult to point out all of the reasons why this method has failed in America and succeeded in Germany. America is more individualistic and the German has been better drilled in discipline and coöperation. The abounding and widely scattered resources of the United States have made it easy for individual enterprise, dispossessed in one place, to seize upon other ore and coal lands, and once more establish itself. The great growth of our market and the demand for steel have demanded new mills, and have got us in the habit of founding new enterprises to which the restlessness and enterprise of our people so naturally adapt themselves. Under these conditions voluntary associations failed, and only the iron hand of ownership could control the American iron and steel makers. And to-day the independents are still springing up and slowly increasing their share of the total industry of the country, but the annexation by the Steel Corporation of another twenty per cent of the productive capacity may easily result from the next period of depression, especially if it starts a steel war.

CHAPTER XI

THE NEW STEELS AND THEIR SIGNIFICANCE

It should be remembered that steel as discussed thus far has been described as an alloy or mixture of carbon and iron. Alloys are peculiar in that they often have qualities possessed by neither parent. The time-honored bronze, a mixture of copper and tin, is much superior to both of its constituents. An alloy is practically the same thing as a solid solution. The two or more metals mingle together as do the sugar, the coffee extract, and the water in a cup of coffee; they become one and inseparable and have a character of their own.

That we have come to think of steel as an iron hardened with carbon only, is practically an accident due largely to historical causes, as for many centuries man could make a good hard cutting metal only from a bar of iron and a pile of charcoal, which is carbon. This material adds strength to the iron but makes it hard, brittle, and liable to crack easily upon cooling. Its effect is almost marvelous. Within a range

limited by 0.05 per cent and 1.5 per cent respectively, this element alone can effect all the changes in character from a soft, malleable, infusible, wrought iron to the opposite of hard, brittle, fine-grained, easily fusible razor steel. In actual practice the greater part of the work of the iron and steel works is nothing more or less than dealing with the alloys of the iron, eliminating, reducing, or adding to them, and giving them the final manipulation to produce the desired results. Some of these alloys are bad and the discovery of processes for their elimination have marked epochs—as witnessed by the name of Bessemer.

Sulphur and phosphorus are the two great ogres of the steel maker. Sulphur makes it crack and tear in rolling, and is so potent in its influence that one one-hundredth of one per cent has a distinctly observable result, and one-tenth of one per cent is the upward limit, beyond which sulphur and utility cannot be combined. Phosphorus is bad and it is mysterious. In the laboratory it may show that the iron has been strengthened by its presence. It tests well, and then in practice comes the catastrophe of unexpected breaks, and this alloy is the one most studiously avoided. Copper happens to be harmless, and also practically without virtue.

Manganese, nickel, and some of the rarer metals have come to the front and are increasing in importance as new and beneficent alloys. One of the troubles of steel is that upon being heated it will make crystals and thereby become weak. This tendency is restrained by the presence of a small amount of manganese, so that it permits the steel to resist greater heat. At the same time it has the allied property of making steel ductile while hot.

Nickel has probably been held as the greatest of the group, and while its importance has at times been overestimated, it has been of very great value in the making of armor plate, because it gives the steel greater strength, a greater tenacity, and resulting from these, a greater resistance to shock, to blows and compression. These, it will be seen, are exactly the qualities to make a piece of metal resist the impact of a shot. In the making of armor plate these qualities are utilized, and a thick plate is made of nickel steel on one side to give it a resisting surface, and of ordinary steel on the other side to make a still more desirable combination of qualities. The steel projectile is made with a sharp, hard point to puncture armor, and an interesting contest of schemes occurred after the discovery that the glass-like surface of nickel steel made

these shells glance before the full force of their impact could be brought to bear on a single spot for the puncturing of the plate. To stop this glancing, some observant inventor devised the scheme of making a soft point to the shell which would be melted by the force of the blow at the instant of contact, and thus melting, would stick like glue to the spot which it struck and permit the shell to exercise the full force of its momentum.

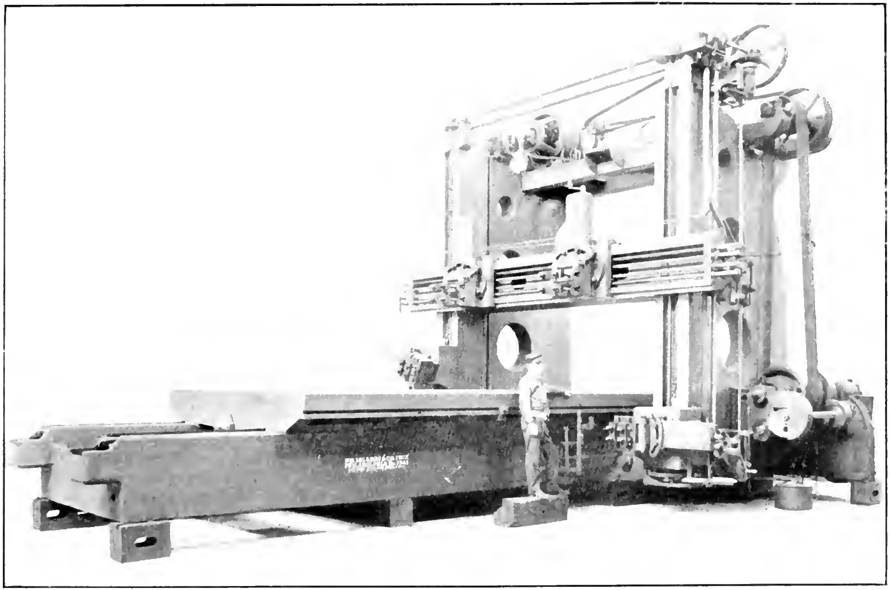
In the measure of real importance, the spectacular nickel steel upon the impressive sides of the ironclad must give way to some of the rarer metals, of which tungsten and chromium are now most important. These are used in the making of tool steel, and they give qualities which the ordinary carbon alone has long and painfully lacked.

It should be remembered that carbon is necessary to iron before it can be fused; and the carbon requisite to give the steel the strength and hardness which we must have, also increases its fusibility, so that comparatively low temperatures make steel approach melting and endanger its efficiency. The machinist recognizes this fact when he knows that getting his tool too hot will spoil its temper and that it can only be retempered by going to a blacksmith shop and being

heated and carefully cooled in a special manner. The experimenter who put into the steel melting crucible certain small quantities of the rare metals tungsten and chromium rendered to the present age an incalculable and generally unappreciated service. These alloys of iron, these new steels, have very high melting points, they have extreme hardness, they will maintain their hardness while they are hot, and do not need tempering.

The importance of this fact comes out in the machine shop where metal cuts metal. Force is everywhere convertible into heat, and the great force required for a chisel to cut steel generates so much heat that the machinist in the old days of a decade or two ago was constantly watching his steel cutting tool to see that it did not become too hot and lose its temper and require a trip to the blacksmith. The life of the plain carbon tool was short and precarious, and required a watchful care which is not necessary for the modern tool of tungsten or chromium steel. Such a tool will cut for hours and maintain uninterrupted its hardness even at red heat, and it never needs tempering, for it is always naturally tempered. This has emancipated the machinist and has made possible the great extension of use of automatic machines.

A very few years ago a man watched a tool to see that it did not, as it soon would, become useless through a slight rise of temperature. He can now set an automatic machine with full confidence that it will work for hours or until it has done its allotted task. By this gift to the metallurgist we have had new horizons opened before the users of machinery, just as the cheap processes for the manufacture of structural steel have opened new horizons before the builders of railroads, of buildings, of ships, and of fences. We are now in the era of machine tools, machines that automatically make machines that will themselves work automatically. To-day a mighty planer will take a huge steel casting as large as the wall of an ordinary room and as thick, clasp it with steel clamps tightly upon its moving bed, and upon the start of the machinery drive it against the chisel so set that, as the bed moves, the chisel cuts its surface. Then, as regularly as a water wheel, the bed moves automatically back and forth for hours with its burden, and the great wall of steel is planed smoothly and evenly. It may be shaped upon any of its four sides, made into curved surfaces, have a hollow interior dressed, or be made into practically any shape desired by industry or by fancy. Thus, the new steels serve industry as the cheap steels have



SPIRAL-GEARED, PNEUMATIC, CLUTCH PLANING MACHINE.

When once started this machine will plane, without further attention, the whole surface of the piece of metal upon which the man's hand rests.

served transportation, commerce, and construction. In quantity they are utterly insignificant, but then the very important teeth are not a large part of the animal that bites.

Within the last few months has been heralded a new alloy made by the introduction of a small quantity of molybdenum. This promises to fill another painful vacancy in the list of qualities desired for steel. This new metal, until recently of no use, is yet exceedingly rare, its use is new, the scope of its usefulness is yet uncertain, but it appears to have the great faculty of preventing the crystallization of steel, due to concussion or vibration. It is a fact, witnessed by many a calamity in the automobile, locomotive, and other vehicles, that mere jar, long repeated, causes the steel to become more and more crystallized, until finally, with no increase of strain whatever, it snaps. So well known is this fact that one of the methods of testing bolts to be used in locomotives is to take samples, put them in a rocker with one end free, and then let them vibrate back and forth, gently tapping a bar. After a varying number of thousands of taps, each expending a force of but a few pounds, a strong steel bar capable of resisting tons at a single strain succumbs to the gentle tapping and breaks apart with a fracture showing clean,

white crystals. The claim is now made that molybdenum makes the steel hold its original qualities because it does not crystallize and does not break; hence, vehicles may be made with much lighter parts because they will last. If these claims are true, we have in the last half century made great progress. First, we have made steel cheaply, that we might use it abundantly for coarser and fundamental uses. Then, we made it hard, so that it will cut even steel as long as desired, and the machinist rejoices. And now comes the new alloy which may give us a vehicle cheaply made by the machinist, and through molybdenum durable against vibration as it runs over the highway, made possible and made cheaply because of the Bessemer converter and the open-hearth process.

CHAPTER XII

THE ORE SUPPLY AND THE STEEL OF TO-MORROW

THE Germans, with their scientific minds, have named mining "The Robber Industry." The farmer who tills a crop and grows it by careful methods can keep on for centuries, as witnessed in China. Even the lumberman, when he fells a tree, knows that by care and waiting another forest will yield other saw logs from the same hillside. But the miner, when he digs beneath the hillside and removes the deposit of ore, knows that it is gone. The question is, how long can the resources of earth stand the robbery? The formation of ore deposits is still going on at the present time, but it is so slow and the product will be so small as to be entirely negligible in the presence of our ferocious demands.

As has been pointed out in the previous chapters of this book, the improvements and growth in the iron industry have been phenomenal, and it is accompanied by an almost appalling consumption of ore. In 1865 the needs of the world

were supplied by a paltry 18,000,000 tons per year, a product not greater than that now yielded by individual American States, and in 1903 the total annual consumption of the world passed 100,000,000 tons. If the present ratio of increase is kept up, the five years from 1935 to 1939, inclusive, will require as much ore as the two decades from 1880 to 1900.

These figures help to explain the fact that the iron industry has been continually roving over the face of the earth in the search for new supplies. Even in the past quarter century, while it has stood still geographically, each of the two great iron-producing regions has had readjustment in its ore supply because of the comparative exhaustion of local supplies and the consequent advantage of importation. The primitive industry of a century ago might and did supply itself decade after decade from the local ore banks, but in this modern day of steam transportation, wide markets, big furnaces, and great production, no smelting district of importance has as yet long continued to depend upon the ores that started it.

This change has been most pronounced in Great Britain, where we have had excellent opportunity to see the rise and fall of local ore districts. That country reached its maximum ore

production about 1880, and since that it has declined sharply. Its decline has been manifest in every ore district, with the single exception of the northeast, which is an exception that may be said properly to prove the rule. This is the region of the famous Cleveland ores. They were too poor to use by the processes known before 1830. Then they rose steadily in importance until 1880, when the original deposits began to show declining output, while a few miles to the south, in the adjacent counties, the same formation appeared as a leaner deposit, which became worthy of notice in 1860, and has of late increased rapidly in importance, making this the only ore district of Great Britain to show an increase of output. In the southwest the Welsh furnaces, in the west the Lancashire furnaces, in the northwest the Scottish furnaces, are all of them using foreign ores, for which, fortunately, they are admirably located, and the supplies can probably be received as easily and cheaply as ore can be delivered at the Pittsburg furnaces from the Minnesota mines. The physical difficulties of delivery are less. The chief British dependence is Spain, where in the region about Bilboa the Spanish mines are conveniently located by the sea and are no farther from the British furnaces than is the head of Lake Superior from the

source of the Ohio. But even from the users of Spanish ores comes the complaint that within the past decade there has been a decline of several per cent in the metallic contents of the imported ores.

Germany, Great Britain's European rival, has also turned to foreign supplies, receiving large shipments from Sweden and Spain and of late having made special arrangements for the receipt of the lower grade ores from Lorraine which had been unused, while the better deposits were worked.

If by some international treaty the northern boundary of the United States had happened to run about 250 miles farther south than it does, we would hear a loud lament that America had no iron ore and was dependent entirely upon foreign supplies. But it so happens that this lament is not heard because of the chance which placed our boundary to the north rather than to the south of the west end of Lake Superior. Our ore revolution has been sharper, more sudden, and more complete than that of Great Britain or Germany. Thirty years ago our iron flowed from furnaces fed with Appalachian ores; Pennsylvania was the leading ore State; New York and New Jersey were important States; whereas at the present time these States are in-

significant in their production. Taken together, they are not yielding five per cent of the country's total. They are not yielding more than one tenth as much as the single State of Minnesota, so completely has our ore supply been shifted to the mines that ship their products in the fleets of lake steamers.

Now that our industry is firmly fixed upon its Lake Superior ore basis, we hear the very definite predictions from those claiming to be experts that within half a century the best ores will be gone from this the most marvelous and richest of the world's ore regions. Already there is a distinct lowering of metal in some of the ore shipped. The practical business men in the iron industry have foreseen the limitation of resources and have secured themselves by buying as much of the deposits as possible, the Steel Corporation alone now possessing above two thirds of the known deposits. This they would not have done if the ore had been sufficiently abundant for plentiful supplies to come from the merchant miners.

In the presence of all these shiftings of ore supply and declines in quality and predictions of exhaustion, it is not surprising that the cry of danger should be heard, and that some persons should entertain alarm for the future. This

alarm is in all likelihood not a matter over which it is wise to spend much time in repining. It is quite likely to be akin to that of our particularly long-headed grandfathers who, solicitous for their grandchildren's welfare, profoundly pondered in the first part of the nineteenth century as to what these poor grandchildren in the year 1900 were going to do to illumine the hours of darkness, for was it not true that every returning whaling captain reported greater and greater scarcity of these leviathans of the briny deep whose inevitable and early extinction was predicted by the scientist? and with them was surely going the supply of good whale oil for the grandchild's family lamp. Impending darkness hung over that child of the future. But what care the grandchildren for whales!

The prophets of an iron famine are thinking of an iron industry which must continue just as the present one now is. They are also underestimating the actual amount of ore deposit at the disposal of the human race. We know but little of the contents of the earth's crust. We are acquainted with small spots of the surface. Most of the surface, even, is practically unknown to us, and so far as minerals are concerned, largely unexplored. We know almost nothing of the 5,000 feet or so beneath the surface, which

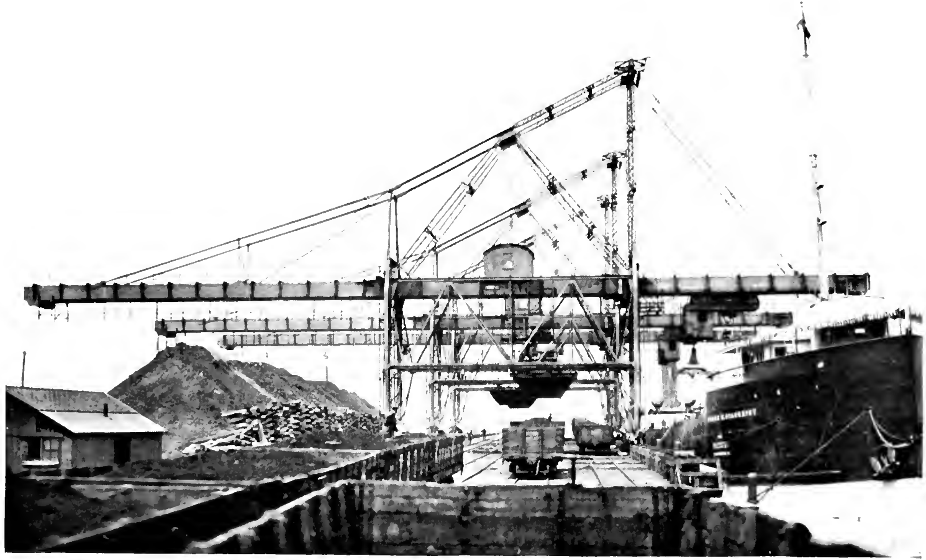
is within our reach. In this connection, it is an astonishing, significant, and withal, hopeful fact, that within the past twelve months there have been five iron-ore deposits of importance discovered in Great Britain, the country of all the world where we might anticipate the knowledge of iron-ore deposits was most complete. It is a small country, with a large mineral industry, and long a leader in the manufacture of iron. If ore deposits can still be found there, what may we expect from the defiles of Asia, from unexplored Canada, the American Rocky Mountains, the forests of South America, and even the arctic wastes? The arctic wastes are not wastes so far as minerals are concerned. One of the most extensive iron deposits in the world is beyond the arctic circle in Sweden, and is now being exploited in a thoroughly modern manner and is sending ore in great quantity to several countries of western Europe.

We must come to a greater transportation of ore. Up to the present generation the iron was made where the ore was mined. We have now begun to carry it about 1,000 miles, but only where the transportation can be by the cheap convenience of ship. We probably have great transportation improvements in store for us in the future. They are certainly still in progress.

We have just developed lightning ore unloaders which unload ore by the ton actually as cheaply as you can send a letter across the street to your neighbor. Within the two years from 1903 to 1905 the average size of the ore steamers then building on the shores of the Great Lakes doubled, and with their doubling in size meant reduction in costs. Twenty-five years hence we may be able to feed our blast furnaces with ore which we will then bring from the iron mountains of Mexico or South America quite as easily as we are now bringing it from the iron ranges of Lake Superior.

In addition to the vast ore deposits and prospective improvements in transportation, there are other reasons why the alarmist should calm himself. We shall have improvements in the process of smelting. Why should human progress stay its fast march in this realm of activity? Within a half century the iron industry has been absolutely revolutionized by technical improvements. Shall that progress stop? Our present knowledge of mankind and the history of the past half century most emphatically say NO.

Iron ores that were high in sulphur or phosphorus were of no more use fifty years ago than any ledge of sandstone. But the compounders of slag have done much to control the sulphur.



ON THE GREAT LAKES. UNLOADING AN ORE STEAMER.

Certain experimenters discovered the so-called basic process, through which, by the exceedingly simple device of lining the melting retorts used in steel making with certain kinds of common stone, the phosphorus is absorbed by the lining, and even changed into a valuable by-product —phosphatic fertilizer. Instantly new vistas opened on the steel horizon. The worthless Michigan mountains of phosphatic ferruginous rock of the geologist became the priceless iron ranges for which steel kings and railroad kings have striven and bargained and paid their millions. The importance of this process cannot be overestimated. The mines of New York and Pennsylvania have languished and the phosphorous ores of Lake Superior have become the amazement of the world. As a consequence States that led in ore production are placed low on the list and do not give three per cent of the country's total. Yet these possessed about all the resources that a prophet of 1855 could have seen with the then existing glasses. Unfortunate indeed would be the plight of a big corporation of 1855 that upon the basis of such prophecies had loaded up for fifty or seventy-five years with merely Pennsylvania nonphosphatic ores in sight. It could not compete with the new supply by the new basic process. There is still plenty of ore in western

Pennsylvania, but it costs $14 a ton to make iron from it, while Superior ore produces it for from $9 to $12.

The Steel Trust and its vast high-priced holdings stand upon the basic process of steel making. Upon what process will the industry of 1925 or 1950 stand? No man knows. Over in Ontario there are mountains of titanic-iron ore. They are reported to be of great extent, but how great no man knows, and no one cares much, for no man can use them. The titanium which they contain, like the phosphorus of the Lake Superior ores fifty years ago, renders the iron useless. Why? The titanic ores may always remain useless, and they may not. Such was not true of the sulphurous and phosphatic ores and the noncoking coals. Just how many chemists and metallurgists are working on that problem it is impossible to state. Chemistry is yet young, and the satisfactory solving of the titanic-ore problem would start us in on a new world of iron resources. Incidentally, it would either drive the Steel Corporation to furious ore purchasing or give some rival a cheaper ore supply.

There are other interesting ore problems equally suggestive. In New York and New Jersey there are large amounts of magnetic ore, but

much of it has a low percentage of iron, requiring too much fuel and handling of dross for profitable smelting. If by some means the iron could be picked out of the dirt and stone it would be as rich as the richest. Mr. Thomas A. Edison put his mind to this task. He ground the ore and dirt as fine as meal, ran it over electrified rollers, to which the iron clove as long as desired to separate it from the nonmagnetizable dirt. So far so good—excellent, indeed, and full of promise; but Mr. Edison lost a million and a half of dollars because he did not happen to be a master of blast-furnace problems. He failed because the force of the air blast through the furnace carried the powdered iron dust away before it could be smelted, and no briquet that he could devise after long and painful trials would hold together until the iron was melted. Mr. Joseph Wharton, who has been said to know more about iron than any man in America, bought some of Mr. Edison's machinery, and is now using the ore successfully by the simple device of not crushing it finer than grains of corn. He is thus profitably making good iron from some ore running as low as twenty to thirty per cent metal. This failure and this success are alike suggestive of progress in iron. The first man rarely reaches the final success with an in-

vention. George Stephenson invented the locomotive about eighty years ago, and that machine, covered from first to last with a thousand patents and improvements, is still growing like a sturdy oak in its prime. Mr. Edison's flour-fine iron is too good a thing to remain unused. Some one will give us girders from it yet. Thus far there has been no semblance of success in the many efforts at concentrating the vast quantities of lean nonmagnetic ores that are widely scattered throughout the country. If it should come there will be 10,000 little mines opened from Maine to California, inclusive.

This whole business of ore concentrating is in its infancy. We have thus far had abundant supplies of rich ore and the concentrating question has not pressed us. In nearly all metals the amount of metal in low-grade ore vastly exceeds that in the rich ores, which are rare. There are vast quantities of low-grade iron ore in Texas, Oklahoma, California, Utah, and many other places in this country, Alaska, and abroad.

The experience of the miners of anthracite coal is suggestive of what may possibly be accomplished with iron ore, of which, in its lower grades, we have such astonishing amounts. For forty years, small coal, which could not be burned in furnaces, was thrown out upon the

culm bank with the slate and dirt which came out of the mine and accumulated to make such an unsightly pile upon the landscape. Then the experts at combustion learned how to burn this small coal, and it was soon found that in addition to the selling of the product as it came from the mine, it could also be won from the culm bank by the simple device of washing it in a manner similar to that by which placer gold is won from the gravel bank. Some similar success with the non-magnetic iron ores would be more revolutionary than was the Bessemer process.

We may also have improvements which will emancipate iron making from dependence upon particular fuels or fuel of any kind.

Another cloud, yet no larger than a man's hand, stands on the steel maker's horizon, but it may rise into the firmament and give us a shower of cheap metal. The electric furnace is already being used in making steel. It is a new process, as yet expensive, but it differs from all others in that the product of the first smelting is high-grade steel. From the blast furnace this result is only attained by expensive processes of refining. It is suggestive that the present tendency is all toward higher grades of steel, and there at the top stands the electric furnace for which it is already claimed that it makes the best of steel as

cheaply as any other process. And the electric furnace, like the forge of Tubal Cain, makes good steel direct from the ore with no intermediate pig stage. This furnace is as yet not an industrial factor, but it may become one any day, through improvements in the realm of smelting or the realm of electricity. The electric smelter is a little thing bearing more resemblance to a bake oven than a blast furnace, which is 100 feet high and costs a million dollars. People are already beginning to speculate upon what will happen when the electric furnace, run by local water power, is installed in the coves of the Appalachian or the Rocky Mountains. It is even claimed that the smelter can become portable and itinerant, like the saw mill. If such a device should accompany some satisfactory process of ore concentration such as Messrs. Edison and Wharton worked on, we should have decentralization of the iron business with a vengeance. Such processes and such decentralization exist in the gold-mining industry, due to comparatively recent discoveries.

One of the most characteristic and most important phases of recent industry has been in the utilization and winning of profit from previously wasted by-products. It has been shown in a previous chapter how the by-product coke oven will

make the coke for nothing, through the sale of by-products at reasonable prices, these by-products having been wasted by other processes. Already there are some blast furnaces using this by-product gas to generate power which they sell. The sale of iron-smelting by-products may become of great importance, particularly as we go to lower-grade ores which give a higher proportion of refuse. Already the extensive use of broken slag for road ballast and for roofing purposes is suggestive. Its use as material for cement at this time, called by many engineers the beginning of the cement age, is much more significant. In Germany, where ores are higher in phosphorus than here, an important industry is arising from the grinding up of the old linings of Bessemer converters and selling them as fertilizer, for they are rich in the prosphorus which they have stolen from the molten iron and which is surprisingly scarce throughout the world and in great demand as plant food by the modern agriculturists.

Some chemist, the modern follower of the alchemists, may some morning announce to the reading world that he has discovered a new alloy of iron which will in some way not now easily predictable cut in half the quantity of that metal which we require to fill our needs and

with the remaining half fill them much more conveniently. Or, again, the same result may come through the success of some of that host who are laboring to reduce the cost of aluminum. The way they have cut down the price of this metal in the past twenty-five years is startling, for they have reduced it much more than half, and if they should even keep up the same percentage in price decline, they would soon have it in the realm where it would compete with the iron. This is the only metal more abundant than iron, and while it cannot take up all of iron's uses, there are many which it can fill in a superior manner.

The future of our supplies of iron and steel is for the generations next ahead of us apparently assured. Just where or how it will be made it would be rash to prophesy, but if the past is any guide to the future, have it we certainly will.

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